CAN MHEALTH, WHEN MONITORED BY A PRIMARY CARE PROVIDER, MAINTAIN HEMOGLOBIN A1C VALUES IN TARGET RANGE WITH ADOLESCENTS BETWEEN THE AGES OF 10-19 DIAGNOSED WITH TYPE 1 DIABETES MELLITUS?

By

Brittany van Viegen

BScN (Honours), Vancouver Island University, 2011

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN NURSING- FAMILY NURSE PRACTITIONER

University of Northern British Columbia

March 2020

Abstract

Diabetes mellitus is an international epidemic affecting millions of individuals worldwide. In Canada, an estimated 3.4 million individuals are living with diabetes mellitus—approximately 9.3 percent of the total population (Canadian Diabetes Association, 2018). A high prevalence of diabetes mellitus comes with a substantial cost; the direct annual cost associated with diabetes mellitus is expected to reach 3.1 billion dollars by 2020 (Bilandzic & Rosella, 2017).

The Canadian Pediatric Society recognizes that there are currently 33,000 children and adolescents aged 5-18 years old living with type 1 diabetes mellitus (T1DM) (as cited in the Diabetic Children's Foundation, 2018). As children and adolescents with T1DM are in the process of developing physically and psychologically, they are at an increased risk of developing complications of diabetes that require short to long term attention and monitoring.

The utilization of mobile technology to provide healthcare services is commonly referred to as mHealth. Such technology offers an opportunity to address the challenges of chronic disease management with this technology- intelligent population (Kitsiou, Paré, Jaana, & Gerber, B. 2017). As a component of the Master of Science in Nursing- Nurse Practitioner program at the University of Northern British Columbia, the following is an integrative review to answer the research question: *Can mHealth, when monitored by a primary care provider, maintain hemoglobin A1c values in target range with adolescents between the ages of 10-19 diagnosed with type 1 diabetes mellitus?*

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Acknowledgement

Without the patience, mentorship, and knowledge of Dr. Caroline Sanders RN, PhD, MBE, BSc (Hons), PGD, PGC, NIHR award(s) and Linda Van Pelt MScN NP-F this project would not have transpired nor would I have been able to complete program. Their expertise, professionalism, and encouragement have been very-much valued during the course of this journey. The amount of gratitude I have for them both is immeasurable.

"One of the greatest values of mentors is the ability to see ahead what others cannot see and to help them navigate a course to their destination." -John C. Maxwell

Dedication

For my family for their unconditional love and support throughout this endeavor. To Sheldon for reminding me that life is about balance and that even in graduate school, you need to take a break and smell the ocean air. To my mom for being by my side yet so far away and for reminding me that nothing worth having is ever easy. To my dad for encouraging me to stay positive, see the light, and find balance on the golf course. To my grandparents who reminded me more than once that anything is possible with hard work and commitment. To my sister— your regular pep talks kept me going on the toughest days. To my niece and nephew who's play time allowed me to recharge. To the Brunt family for cheering me on since day one, for always having the tea kettle plugged-in and ready to-go, and for providing me with distraction time to watch Jeopardy. To Reggie for keeping me on-task while keeping my feet warm under the desk— our endless adventures await.

To my friends who encouraged me, adapted to my schedule, and remembered who I was when the semesters were over. To my classmates who allowed me to learn alongside them in a supportive environment. To my preceptors and clinical faculty members who offered their wealth of knowledge and exhibited mentor qualities I hope to one day pass-on. This is for each of you, for without you this adventure never would have been possible.

Glossary

All citations are from Medical Dictionary (2017) unless otherwise indicated.

adherence- the act, action, or quality of adhering; to give support or maintain loyalty

compliance- the act or process of complying to a desire, demand, proposal, or regimen or to coercion

exogenous insulin- insulin not produced by the body (Donner, 2015)

glucose- a crystalline sugar C6H12O6; specifically, the sweet colorless soluble dextrorotatory form that occurs widely in nature and is the usual form in which carbohydrate is assimilated by animals

gluconeogenesis- formation of glucose within the animal body from precursors other than carbohydrates especially by the liver and kidney using amino acids from proteins, glycerol from fats, or lactate produced by muscle during anaerobic glycolysis

hard endpoint- an endpoint that is well-defined and can be measured objectively (European Patients' Academy, 2018a)

hemoglobin A1c- a blood test utilized to measure the amount of HgbA1c in the blood which provides an accurate long-term measure of an individual's average blood glucose level within the previous three months (Pagana, K., Pagana, T., & Pike-MacDonald, 2012)

hyperglycemia- an excess of sugar in the blood

hyperketonemia- a condition marked by an abnormal increase of ketone bodies in the circulating blood —called also ketonemia

hyperosmolality- the condition especially of a bodily fluid of having abnormally high osmolality

ketosis- an abnormal increase of ketone bodies in the body

lipogenesis- the formation of fat; specifically, the formation of fatty acids from acetyl coenzyme A in the living body and especially in adipose tissue and the liver

metabolic acidosis- acidosis resulting from excess acid due to abnormal metabolism, excessive acid intake, or renal retention or from excessive loss of bicarbonate (as in diarrhea)

osmotic diuresis- increased urination due to the presence of certain substances in the fluid filtered by the kidneys. This fluid eventually becomes urine. These substances cause additional water to come into the urine, increasing its amount. Causes include increased glucose in the blood and certain medications (US National Library of Medicine, 2018)

pancreatic beta cells- any of the insulin-secreting pancreatic cells in the islets of Langerhans

pH- a measure of acidity and alkalinity of a solution that is a number on a scale on which a value of 7 represents neutrality and lower numbers indicate increasing acidity and higher numbers increasing alkalinity and on which each unit of change represents a tenfold change in acidity or alkalinity and that is the negative logarithm of the effective hydrogen-ion concentration or hydrogen-ion activity in gram equivalents per liter of the solution

polydipsia- excessive or abnormal thirst

polyuria- excessive secretion of urine

CHAPTER ONE: INTRODUCTION

Diabetes mellitus has developed in to an international epidemic affecting millions of people around the world. In Canada, an estimated 3.4 million individuals are living with diabetes mellitus—approximately 9.3 percent of the total population (Canadian Diabetes Association [CDA], 2018). The total number of Canadians diagnosed with diabetes is expected to increase to 5 million by the year 2025 with a projected annual direct cost of $3.1 billion in 2020—increases of 44 percent to prevalence and 25 percent to cost (CDA, 2018; Bilandzic & Rosella, 2017). Canada is recognized as having one of the highest incidence rates for type 1 diabetes mellitus (T1DM) globally in children and adolescents under the age of fourteen (DiaMond Project Group, as cited in the Public Health agency of Canada [PHAC], 2011). According to the Canadian Pediatric Society (CPS) 33,000 children and adolescents between the ages of 5-18 years old are living with T1DM (as cited in the Diabetic Children's Foundation, 2018). Although Canada does not currently have statistics available for the prevalence of T1DM and T2DM in adolescents, British Columbia's Provincial Health Services Authority (2010) estimated that approximately ninety percent of diabetes mellitus cases in the paediatric population were type 1 and approximately ten percent were type 2, however the data was extracted over an eleven-year period ending in 2007. Although an increase in the prevalence of T1DM has been documented in several countries globally, the rationale for the rise remains unclear (PHAC, 2011).

Type 1 diabetes mellitus (T1DM), previously called insulin-dependent or juvenile diabetes, results in an insufficient amount of insulin in the body due to two possible reasons: (1) the destruction of pancreatic beta cells which produce insulin, or (2) idiopathic causes (Brashers, Jones, & Huether, 2014). An excess of glucose in the body results due to the insufficiency of pancreatic beta cells, placing the individual at risk for potentially life-threatening complications

if left untreated. Unlike T1DM, T2DM is predominately associated with insulin resistance and strongly linked to obesity (Brashers et al., 2014). Both T1DM and T2DM place an individual at risk for cardiovascular disease, retinopathy, nephropathy, and neuropathy (Brashers et al., 2014). However, because T1DM is generally diagnosed at a younger age there is an increased risk of developing long-term complications at an earlier age (PHAC, 2011). Furthermore, because individuals diagnosed with T1DM rely on exogenous insulin to normalize metabolic processes, there is an additional risk of immediate and acute complications (PHAC, 2011).

Adolescents diagnosed with T1DM are known to have less effective metabolic control in comparison to other age categories (Moore et al., 2013). While the onset of T1DM generally occurs before or during adolescence it is recognized that this stage of development is a time of significant physical, cognitive, and psychological change. In addition, youth are at an increased likelihood of engaging in high-risk behaviours (for example, alcohol and drug use) and developing mental health conditions (Moore et al., 2013; World Health Organization [WHO], 2017). As a result of onset in childhood or adolescence, parental support and monitoring is a key aspect of childhood T1DM health care management (Smith, Cheater, & Bekker; Wallander & Varney, 1998). While the rate of engaging in risk-taking behaviour is similar amongst adolescents diagnosed with T1DM and non-T1DM adolescents, the outcome for an individual with T1DM who engages in high-risk behaviour is linked to poor metabolic outcomes, personal and family stress, and mental illness (Moore et al., 2013).

As a result of software, connectivity, and increased social economy, digital access has become widely available to younger populations across a broader network and geography. Subsequently, the use of technology in the management of life long or chronic conditions has developed significantly and continues to evolve. Originally, the term *telemedicine* encompassed

health care services offered from a distance. However, the use of technology in health care has expanded resulting in a range of sub-categories within a framework of telemedicine, including mHealth (Kitsiou et al., 2017). As such, mHealth utilizes mobile technologies to provide health care services; in relation to adolescents diagnosed with T1DM, mHealth has the potential to:

- support adolescents diagnosed with T1DM in gaining autonomy in management of their chronic disease;
- provide parents with the ability to monitor their child's daily T1DM-related values;
- provide health care providers the opportunity to communicate with the patient, monitor daily T1DM values, provide T1DM guidance and counseling, and create and revise treatment plans accordingly (Kitsiou et al., 2017).

The following is an integrative review investigating *if mHealth, when monitored by a primary care provider (PCP), can maintain HgbA1c values in target range with adolescents between the ages of 10-19 diagnosed with T1DM*. Glycosylated hemoglobin, or HbgA1c, is a blood test utilized to measure the amount of HgbA1c in the blood and provides an accurate long-term measure of an individual's average blood glucose level within the previous three months (Pagana, K., Pagana, T., & Pike-MacDonald, 2012; Juarez et al., 2013). A stable HgbA1c of less than 7.0-7.5 percent is often associated with a reduction in complications associated with T1DM such as long-term microvascular and macrovascular risks and avoidance of excessive episodes of severe hypo-or hyper-glycemia (Canadian Diabetes Association Clinical Practice Guidelines Expert Committee [CDACPGEC], 2013; Juarez et al., 2013; Wherrett, Huot, Mitchell, & Pacaud, 2013). The Diabetes Control and Complications Trial Group [DCCT] (1995), recognized that a ten percent reduction in the HgbA1c of individuals diagnosed with T1DM resulted in a 40 to 50 percent reduction in retinopathy in addition to a decrease in microvascular complications;

although the trial was conducted with a predominately adult population, it emphasizes the importance of maintaining HgbA1c in therapeutic range in order to limit complications (Nathan, 2014).

Following an integrative review approach, this paper will provide background context of the key ideas associated with the research topic, including: a definition of adolescence; the pathophysiology, clinical presentation, complications, HgbA1c, diagnostic criteria and glycemic targets, and management of T1DM; adherence to T1DM management amongst adolescents; parental or caregiver involvement with adolescents diagnosed with T1DM; an overview of the use of technology in the adolescent population; a summary of the concept of mHealth; and the role of primary care providers in chronic disease management. The search strategy conducted to answer the posed research question will be identified, including: conceptualization and the preliminary search, the focused search, and analysis of the articles selected for the integrative review. The common themes identified from the analysis will then be expanded in the Findings section followed by the Discussion section which will synthesize the Findings and include recommendations for the clinical setting, education, and future research.

CHAPTER TWO: BACKGROUND AND CONTEXT

In order to gain a better understanding of the complexities associated with adolescent individuals diagnosed with T1DM, there are several key components that need to be addressed in further detail. These components include: adolescence; the pathophysiology, clinical presentation, complications, HgbA1c, diagnostic criteria and glycemic targets, and management of T1DM; adherence to T1DM regimens amongst adolescents; parental or caregiver involvement with the T1DM management plan for adolescents; the correlation between technology and adolescents; an overview of technology in health care including a summary of the concept of mHealth; and the role of primary care providers. The following sections will expand the key components with an aim to contextualize the place mHealth has within primary care management with the T1DM adolescent.

Adolescence

There are various meanings to the term *adolescence* throughout the literature. The World Health Organization [WHO] (2017, para. 2) and the Canadian Paediatric Society [CPS] (2016, para. 3) both recognize adolescence as the growth and development phase between childhood and adulthood, from the ages of ten to nineteen. The CPS further identifies that "adolescence begins with the onset of physiologically normal puberty, and ends when an adult identity and behavior are accepted" (2016, para. 3). The American Psychological Association [APA] describes the term adolescence as a period of physical growth and social and cognitive development, or the amount of time from the onset of puberty to the period when an individual obtains financial independence (2002). Furthermore, the WHO identifies adolescence as one of the most rapid periods of growth and development across the lifespan (2017). The WHO and CPS' definition of adolescents will be recognized within this paper—an individual between the

ages of ten and nineteen experiencing rapid growth and development between childhood and adulthood.

During adolescence several developmental milestones occur. Such milestones include: sexual maturation, physical growth, increased social and economic responsibilities and independence, increased ability for abstract reasoning due to pre-frontal cortex development, the acquisition of skills necessary for maintaining adult relationships and responsibilities, and the development of one's identity (WHO, 2017; APA, 2002). Furthermore, adolescence is a period associated with poor understanding of the correlation between risks and consequences due to the evolving development of the pre-frontal cortex which is responsible for executive functions, including: decision-making, organizational skills, impulse control, and long-term planning and goal (WHO, 2017). The continuing development of the pre-frontal cortex during adolescence contributes to challenges associated with chronic disease management, such as T1DM, therefore adolescents diagnosed with T1DM benefit from being closely monitored and well-supported.

Type I Diabetes Mellitus in Adolescents

Diabetes mellitus is a syndrome characterized by hyperglycemia due to defects in insulin secretion, insulin action, or a combination of both (Brashers et al., 2014). T1DM is a predominately autoimmune syndrome whereas type 2 diabetes mellitus is characterized by insulin deficiency and resistance. The diagnosis of T1DM in childhood or adolescence can be challenging for the individual; however, parents, care providers, school teachers, sports coaches, etc. are also impacted by the attention that an adolescent with T1DM requires. Regular insulin injections, blood glucose monitoring, and diet and physical exercise needs can be life-changing, in addition to the necessary attention required when acute and chronic complications develop (Caferoğlu, İnanç, Hatipoğlu & Kurtoğlu, 2016). The following section will discuss the

pathophysiology, clinical presentation, complications, HgbA1c, diagnostic criteria and glycemic targets, and management of T1DM.

Pathophysiology

The disease process of T1DM is multifaceted. Pancreatic beta cells which produce insulin in the pancreas are destroyed resulting in insulin deficiency and hyperglycemia secondary to a defective metabolism of fat, protein, and carbohydrates in the body (Atkinson, von Herrath, Powers, & Clare-Salzler 2015; Brashers et al., 2014; Paschou, Papadopoulou-Marketou, Chrousos, & Kanaka-Gantenbein, 2018; Smaldone, Steiner, & Whittemore, 2017). As glucose accumulates in the body due to insulin deficiency, reduced effectiveness, or both, the kidneys become unable to maintain the amount of glucose in the body resulting in *osmotic diuresis* and symptoms of *polyuria* and *polydipsia* (Brashers et al., 2014; Smaldone et al., 2017). Furthermore, weight loss occurs due to fluid loss and loss of body mass which is associated with the breakdown of protein and fat (Brashers et al., 2014). Because insulin stimulates *lipogenesis* which results in stored fats, there is an increased amount of fatty acids delivered to the liver which causes hyperglycemia due to increased *gluconeogenesis* (Brashers et al., 2014). Insulin deficiency further contributes to the release of fatty acids and an increased production of ketone bodies by the liver at a rate that exceeds use by the body; the increase in ketone bodies decreases the *pH* (to an acidotic state) which triggers the buffering system associated with *metabolic acidosis* (Brashers et al., 2014; National Health Service [NHS], 2017). At this stage, diabetic ketoacidosis may occur which is life-threatening and initially caused by the lack of circulating insulin; approximately one quarter of children with new-onset T1DM present in diabetic ketoacidosis (Brashers et al., 2014; NHS, 2017; Smaldone et al., 2017).

There are two distinct types of T1DM: autoimmune and non-autoimmune. In autoimmune diabetes, both environmental and genetic factors are thought to trigger cell-mediated destruction of the beta cells which are responsible for producing insulin in the pancreas (Brashers et al., 2014). The result of beta cell destruction leaves the body with minimal or no insulin which is required to avoid hyperglycemia and potential short and long-term complications. T1DM that is autoimmune-related is recognized as a subtype and identified as *type 1A,* contributing to 95% of all T1DM cases (Brashers et al., 2014; Masharani, 2016). Type 1B diabetes mellitus is of idiopathic (non-autoimmune) origin accounting for approximately 5% of all T1DM (Brashers et al., 2014; Masharani, 2016). These will be explained briefly in the next subsections.

T1DM 1A. Here, the immune system attacks beta cells resulting in reduced insulin secretion. Autoimmunity has been associated with genetic or environmental factors which cause autoantigens to form on beta cells and travel throughout the blood and lymphatic system which triggers a response from the immune system resulting in beta cell destruction and ultimately insulin deficiency and hyperglycemia (Brashers et al., 2014; Kalyani, 2017).

Approximately one-third of T1DM susceptibility is attributed to genes; the other two-thirds are related to environmental factors (Masharani, 2016). The lifetime risk of developing T1DM is significantly higher if an individual has a family history of the disease (Brashers et al., 2014). Furthermore, there are several additional factors suggested to be linked to an increased risk of T1DM 1A including: viral infections (particularly enterovirus), diet (specifically exposure to cow's milk, fruit, or gluten at an early age), higher socioeconomic status, exposure to toxins. obesity, vitamin D deficiency, gut microbiota reduction, and perinatal factors including maternal

age, history of preeclampsia, neonatal jaundice, and a low birth weight (Brashers et al., 2014; Saberzadeh-Ardestani et al., 2018).

T1DM 1B. Approximately 5% of individuals diagnosed with T1DM have no evidence of pancreatic autoimmunity to explain the body's inability to provide an adequate amount of insulin; this subgroup of diabetes mellitus is identified as "idiopathic type 1" or type 1B (Kalyani, 2017; Papadakis & McPhee, 2016). Individuals diagnosed with type 1B diabetes mellitus are predominately Asian or African; however, there is little information available on type 1B diabetes mellitus available across ethnicities resulting in possible population bias (Balasubramanian et al., 2003; Kalyani, 2017; Papadakis & McPhee, 2016). Despite variation in the pathophysiology presentation of either type of T1DM (A or B), the clinical presentation follows a similar pattern and is discussed in the following section.

Clinical Presentation

T1DM is the most common type of diabetes in children under the age of 12; diagnosis of T1DM is extremely rare under the age of nine months and peaks between the ages of 11-13 years (Brashers et al., 2014; Smaldone et al., 2017). There is no gender difference of T1DM in the overall incidence between males and females; however the peak onset of T1DM is slightly earlier in females in comparison to males (Brashers et al., 2014). Furthermore, T1DM has a higher prevalence amongst those of Caucasian decent; the rates are approximately 1.5-2 times higher that non-white individuals (Brashers et al., 2014).

T1DM was historically thought to have an abrupt onset, however research has confirmed that it occurs over an extended period of time in which beta cells of the pancreas are destroyed leading to insulin deficiency and hyperglycemia (Brashers et al., 2014; Smaldone et al., 2017). Prior to hyperglycemia, approximately 80% to 90% of the function of insulin-secreting beta cells

must be lost (Brashers et al., 2014). The symptom set of T1DM may present clinically in a variety of ways. The most common presentation of T1DM in children and adolescents is a combination of: polydipsia, polyuria, polyphagia, weight loss, and fatigue contributed to hyperosmolality and *hyperketonemia* from an increased amount of circulating glucose and fatty acids and insulin deficiency (Brashers et al., 2014; Masharani, 2016). Polyuria and polydipsia are present in approximately 90 percent of individuals; however, these symptoms may become more apparent with a thorough health history including nocturia (nighttime voiding), bedwetting, an increased number of wet diapers or abnormally wet diapers, and persistent thirst (Brashers et al., 2014). If left unrecognized and untreated for a significant amount of time, T1DM may progress into diabetic ketoacidosis (DKA) which is a life-threatening condition. The complications associated with T1DM will be discussed in the following section.

Complications

Diabetic complications are a significant cause of morbidity and mortality amongst individuals diagnosed with T1DM (Smaldone et al., 2017; You & Henneberg, 2016). Individuals diagnosed with T1DM are ten-times more likely to experience a cardiac event (macrovascular complication) than non-diabetic individuals of the same age (Atkinson, Eisenbarth, & Michels, 2014). In the adolescent population, poor glycemic control, changing physiology, and behavioural and adherence issues can be causative factors in acute and chronic complications of T1DM (Al-Agha, Ocheltree, & Hakeem, 2011). However, daily self-monitoring of blood glucose, daily insulin injections, regular hemoglobin A1c (HgbA1c) measurements, and close monitoring of physical activity can aid in the reduction of T1DM-associated complications (Al-Agha et al., 2011; CDACPGEC, 2013).

In addition to microvascular and macrovascular complications, undesired outcomes specific to the T1DM adolescent population have been identified, including: cognitive alterations affecting learning and executive functions, brain structure alterations, brain activity alterations, sleep disorders, disrupted eating behavior/eating disorders, self-reported low quality of life, depression and anxiety, and increased absences from school (Litmanovitch, Geva, & Rachmiel, 2015; CDACPGEC, 2013). Ultimately, glycemic control within target range can reduce the risk of micro and macro-vascular complications and undesired outcomes.

Diabetic ketoacidosis. DKA, the leading cause of morbidity and mortality amongst children and adolescents diagnosed with T1DM, is a result of absolute insulin deficiency (Jeha & Haymond, 2016; Diabetes Canada, 2018). The diagnosis of DKA involves hyperglycemia (a blood glucose greater than 11 mmol/L), metabolic acidosis (a venous pH less than 7.3 or plasma bicarbonate greater than 15 mmol/L), and *ketosis* (ketones present in urine, blood, or both) (Jeha & Haymond, 2016). The clinical presentation of DKA may include polydipsia, polyuria, polyphagia, weight loss, and fatigue in addition to a fruity smelling breath, tachycardia, and neurological symptoms including decreased level of consciousness and lethargy (Brashers et al., 2014; Diabetes Canada, 2018; NHS, 2017). Vomiting may also be present due to dehydration. There are three levels of severity of DKA, including: mild, moderate, and severe. Unfortunately, nearly 50% of children under the age of 4 and 25% of those between the ages of 5 and 15 present with DKA as the initial sign for T1DM (Brashers et al., 2014; Smaldone et al., 2017). Children and adolescents presenting with DKA are often admitted to hospital requiring rehydration and intravenous insulin therapy; in British Columbia, those with mild DKA, known T1DM, and reliable support may be managed at home or as an outpatient, however all individuals presenting with moderate or severe DKA are managed optimally in a medical facility (Brashers et al., 2014;

Metzger, 2010). As there are significant risks associated with hyperglycemia and hypoglycemia, it is essential for adolescents diagnosed with T1DM to stay within their glycemic target in order to avoid complications. Glycohemoglobin testing, diagnostic criteria, and glycemic targets of T1DM will be discussed in the following section.

HgbA1c, Diagnostic Criteria and Glycemic Targets

HgbA1c, or a glycohemoglobin test, is recognized as "a blood test that checks the amount of sugar (glucose) bound to hemoglobin in red blood cells" (Government of Alberta, 2020). Individuals who have T1DM or T2DM have an elevated amount of glucose bound to hemoglobin. An HgbA1c test is used to diagnose pre-diabetes, T1DM, T2DM, gestational diabetes, or for the purpose of monitoring diabetes mellitus (Government of Alberta, 2020; HealthLinkBC, 2018). Unlike self-monitoring of blood-glucose which evaluates the blood sugar in the moment that the test is conducted, HgbA1c captures the amount of glucose in the blood over the previous two to three months as the life cycle of a red blood cell is three to four months in length (Government of Alberta, 2020; HealthLinkBC, 2018).

The diagnostic criteria for diabetes mellitus are complex but offer important considerations when exploring HbA1c values as key goals in treatment. Diabetes Canada (2018) advises that the diagnosis of diabetes mellitus (both types 1 and 2) in children, adolescents, and adults includes the following criteria:

- a fasting plasma glucose ≥ 7.0 mmol/L (no intake for a minimum of 8 hours prior to the test);
- a hemoglobin A1C ≥ 6.5% (not recommended as the sole diagnostic test in children and adolescents);
- a 2-hour plasma glucose ≥ 11.1 mmol/L in a 75g oral glucose tolerance test;

- a random plasma glucose of ≥ 11.1 mmol/L in an individual displaying symptoms of hyperglycemia.

If an asymptomatic individual suspected of having diabetes mellitus tests positive to one of the above tests, the test is considered a false positive; a repeat test is required to provide confirmation of diagnosis, preferably the same test scheduled on a different day in a timely manner (Chiang et al., 2018; Diabetes Canada, 2018; Medical Services Committee, 2015). When an individual is symptomatic of diabetes mellitus, secondary testing is not necessary to confirm diagnosis. While HgbA1c testing is not currently recommended for diagnosis in children and adolescents, there is ongoing work exploring the value in using HgbA1c in the future (Chiang et al., 2018; Diabetes Canada, 2018).

To distinguish between T1DM and T2DM, determining the presence of pancreatic autoantibodies is necessary. The types of autoantibodies include: islet cell cytoplasmic autoantibodies (ICA), insulin autoantibodies (IAA), glutamic acid decarboxylase autoantibodies (GADA), glutamic acid decarboxylase-65 autoantibodies (GAD-65), insulinoma-associated-2 autoantibodies (IA-2A), and zinc transporter-8 Autoantibodies (ZnT8A) (American Association for Clinical Chemistry [AACC], 2018; Donner, Champaneri, & Saudek, 2015). GAD-65 autoantibodies are present at clinical presentation in approximately 80 percent of individuals diagnosed with T1DM whereas IAA is the first marker present in children who are at-risk for T1DM and is present at diagnosis in approximately 70 percent of cases (AACC, 2018). However, a lack of autoantibodies does not rule out the presence of T1DM as the disease process may be idiopathic (type 1B), not autoimmune (type 1A).

Once an individual is diagnosed with T1DM, maintaining glycemic control is critical in preserving homeostasis and reducing the risk of complications. The glycemic targets

recommended for children and adolescents are: an HgbA1c ≤7.5%, a fasting (preprandial) glucose of 4 to 8 mmol/L, or a two-hour post-prandial glucose of 5 to 10 mmol/L (Wherrett et al, 2018). However, if a child or adolescent is susceptible to hypoglycemic episodes a higher HgbA1c and preprandial target may be advised by the individual's diabetic team (American Diabetes Association, 2018; Wherrett et al, 2018). In order to maintain HgbA1c within a therapeutic range, measures are taken to reduce hypo and hyperglycemic events and regulate HgbA1c. The following section will provide an overview of the management of T1DM.

Management

There is currently no cure for T1DM; therefore, individuals diagnosed with T1DM have a chronic disease that can be life-limiting. Smaldone et al., recognize that "the treatment goals for children [and adolescents] are to achieve normal growth and development, optimal glycemic control, and positive psychosocial adjustment to diabetes while minimizing acute or chronic complications" (2017, p. 610). Therefore, children and adolescents diagnosed with T1DM must learn to self-manage their disease to in order to minimize risk and associated complications (Distiller, 2014). Effective management is critical if outcome goals of HgbA1c levels are to be released by the adolescent. However, management is complex as Coffen (2009) reports that there are over six hundred tasks an individual will need to master, including; understanding of the etiology of the disease, knowledge of pharmacology (including insulin), insulin technique, blood glucose and ketone monitoring, diet, exercise, hypoglycemia, hyperglycemia, diabetic ketoacidosis, illness and stress, traveling, complications, general knowledge, and miscellaneous items. Glycemic control, as evidenced by HgbA1c monitoring, has been associated with reducing or preventing complications (Diabetes Control and Complications Trial Research Group, 1995).

Insulin is necessary for glycemic control and is a mainstay of management for adolescents diagnosed with T1DM. Insulin is initiated at the time of diagnosis and is a complex and often overwhelming process for patients (American Diabetes Association, 2019; Diabetes Canada, 2018). When an insulin regimen is initiated, there are a multitude of factors to consider from a health care provider perspective in terms of selection. Such factors include: age, overall health/co-existing chronic diseases, treatment goals, lifestyle, diet, hypoglycemia awareness, ability to self-manage, and adherence to treatment regimen as there is not a "one size fits all" strategy to selecting insulin and there are multiple types of insulin available in Canada (Diabetes Canada, 2018). Furthermore, patients diagnosed with T1DM often require multiple types of insulin complicating the process further (Diabetes Canada, 2018).

The management of T1DM in adolescents is additionally complicated by physiological and psychological changes of adolescence. Youth between the ages of 10-19 years are experiencing physical, psychosocial and emotional challenges by nature of their growth and cognitive development (Datye et al., 2015; Taddeo, Egedy, & Frappier, 2008). Maturation and progression towards independence is essential at this stage. In British Columbia, adolescents and their families work together with primary care providers, specialists, nurses, social workers, therapists, school, and community and government organizations to ensure there is a smooth transition to the adult care system; key components of this process include providing adolescents and their families with the confidence, skills, and knowledge required to transition to adult care (BC Children's Hospital, 2016). For youth with T1DM, the positive influence of health education and management are critical in promoting self-efficacy and subsequently the transition towards adult care provider systems (Paterick, Patel, Tajik, & Chandrasekaran, 2017). Extensive education involving the disease process, management, and potential complications of T1DM is

offered to youth from health care providers at the initial time of diagnosis and support is most often maintained, by paediatric-led teams, until the individual turns 19 years of age; at this time, primary care providers take a greater responsibility in on-going care (Provincial Health Services Authority [PHSA], 2017; Wherrett, Huot, Mitchell, & Pacaud, 2013). One major worry is associated with development, access, and independence and is commonly framed within the concept of adherence to medication regimen. As non-adherence has significant impact on short and long-term health outcomes for individuals diagnosed with T1DM, it warrants further examination which will be provided in the following section. However, it is important to briefly recognize the management of diabetes in schools in British Columbia as adolescents spend a large amount of their time in this environment and must learn to manage their disease in various contexts.

Due to management complexities of T1DM in children and adolescents including various types of insulin, the risk for hypo and hyper-glycemic events and diabetic complications, periods of increased physical activity, etc. adolescents diagnosed with T1DM must learn to manage their chronic disease in various contexts. A collaborative effort by the Ministries of Health, Education, and Children and Family Development resulted a guideline for children and adolescents enrolled in public schools diagnosed with T1DM; 'Supporting Students with Type 1 Diabetes in the School Setting' outlines "the provincial standards to support students with T1DM in the school setting, and articulate[s] the roles and responsibilities of parents/guardians, the school administer, and the Health Authorities" (2015, p. 2). Recognizing the challenges that children and adolescents diagnosed with T1DM encounter, the ultimate goal of the program is to ensure students diagnosed with T1DM are offered an equitable education in a safe learning environment.

Despite abundant literature available linking well-managed T1DM with an HgbA1c within target range to reduce complications, non-adherence to T1DM management can be a challenge amongst the adolescent population especially when multiple environments are a factor. Not only do different environments have a potential to impact diabetic management and health outcomes, adherence also has a significant impact on health outcomes and the risk for complications. The following section will discuss adherence to T1DM management in adolescents.

Adherence

The annual costs associated with non-adherence of individuals diagnosed with diabetes are significant. T1DM is a costly chronic condition costing between 100 and 289 billion dollars in the United States and is linked to approximately 125,000 deaths and 10% of hospitalizations annually, (Dunbar-Jacob & Mortimer-Stephens, 2001; Viswanathan et al., 2012; Watanabe, McInnis, & Hirsch, 2018).While similar statistics are unavailable for Canada, T1DM affects approximately 3.4 million Canadians which is expected to increase to 5 million by 2025 (Bilandzic & Rosella, 2017). Well-managed physical health in T1DM is often labeled as good adherence within health care environments. Venes identifies adherence as "the extent to which a patient's behavior coincides with medical advice"; whereas *non-adherence* is the contrary and associated with negative connotation, not following medical advice, ineffectiveness of treatment, and poor health care outcomes (2001, p. 461; WHO, 2003). The concept of adherence is relevant to this integrative review since adolescence is a developmental period during which adherence is low (Wherett et al., 2018). In terms of mHealth and adolescents diagnosed with T1DM, mHealth is proposed as an approach to improve adherence management.

Adherence-related tasks relevant to an adolescent diagnosed with T1DM may include: routine blood glucose monitoring, insulin and/or glucose administration, additional medication administration, attention to diet and activity, attending medical appointments, having routine blood draws at the laboratory, obtaining and maintaining medical supplies, etc. (Gandhi et al., 2016). Amongst individuals diagnosed with T1DM, adherence is associated with maintaining glycemic control as evidenced by HgbA1c levels (Hamine et al., 2015; Horne et al., 2005). As T1DM is a complex chronic disease and adolescence is associated with poor adherence, parental or caregiver involvement and support is essential which will be discussed in the following section.

Parental Involvement

T1DM is a complex chronic disease requiring multiple daily tasks and attention to detail, therefore a lack of T1DM knowledge or failure to engage in behavioural tasks may result in short or long-term complications requiring further medical care (Herge et al., 2012; Taddeo et al., 2008). Due to the attention of detail required and risk of patient safety of not engaging in such tasks, adolescents diagnosed with T1DM may feel extremely overwhelmed. Therefore, parental involvement and support in the management of T1DM is necessary as adolescents work towards increasing their independence in managing their chronic disease.

An adolescent's relationship with his or her parents can play a significant role in the development of self-care, adherence to diabetic care routine and metabolic control (Berg et al, 2011). However, the responsibility of managing a child or adolescent diagnosed with a chronic disease, such as T1DM, increases the demands of parenting and providing care significantly (Smith et al., 2013; Wallander & Varney, 1998). In addition to regular demands of parenting, parents and care givers must adapt to disease-specific demands, including: maintenance of

treatment and care, avoiding complications, social and financial constraints, and maintenance of family relationships and life (Smith et al., 2013). When there are effective strategies to manage the adolescent's condition and cope with disease-associated stressors there, is a noticeable improvement in family functioning (Smith et al., 2013). Although close monitoring of an adolescent may be beneficial to T1DM outcomes, it may also hinder the parental-adolescent relationship as adolescents seek independence.

Parents of adolescents diagnosed with T1DM recognize that adolescent self-management is reduced when scolding, judging, checking, nagging, or becoming emotional is displayed by the parent and ultimately associated with the stress and anxiety of having a child diagnosed with a complex chronic disease (Carroll, Downs, & Marrero, 2007; Moore et al., 2013). Parents and care givers often struggle with providing the adolescent with autonomy in relation to managing T1DM because adolescents often recognize themselves as more capable and independent at an earlier age than their parents, (Butner et al., 2009; Carroll et al., 2007). Additional support during this transitional time, when adolescents diagnosed with T1DM are seeking self-efficacy and independence, may foster healthier relationships with parents. In the context of this paper, mHealth could provide a platform for reassurance as parents could gain access to adolescent's diabetic data (such as blood glucose readings or insulin dosages) and have comfort in knowing there is increased accessibility to communication between adolescents and health care providers—depending on the app selected. Adolescents are well-known for their usage of electronic devices and software, therefore utilizing technology to support management of T1DM in adolescents may promote independence, improve adherence and subsequently maintain HgbA1c within target range (George & Odgers, 2014). The following section will discuss the relationship between technology and adolescents.

Technology and Adolescents

Adolescents have traditionally been keen to explore new technologies and are amongst one of the highest user groups (George & Odgers, 2014; Moawad & Ebrahen, 2016). Due to the convenience and accessibility delivered by mobile devices, 92% of American adolescents report utilizing the internet daily; furthermore, 24% of those identified reported being online almost constantly (Lenhart, 2015). In Canada, approximately 24% of Grade 4 students, 52% of Grade 7 students, and 85% of Grade 11 students own or have access to a cellphone or smartphone which is associated with familial socioeconomic status (Johnson, 2015). Anderson and Jiang (2018) report that approximately 95 % of Canadian teens between the ages of 13 and 17 have or have access to a mobile phone; a 22% increase from the previous statistics in 2014-2015. Of the 95% of teens, almost all send and receive text messages; the average teen sends approximately 30 text messages per day (Anderson & Jiang, 2018, para. 5). Additionally, the majority (51%) of grade 11 (ages 16/17) students are sleeping with their mobile devices in reach; 20% of grade 4 (ages 9/10) (Johnson, 2015).

Canadian youth utilize technology and the Internet for many reasons, including: socializing, news and current events, seeking information regarding health and well-being (physical and mental health, sexuality, relationship concerns, etc), playing games, etc. (Johnson, 2015). Furthermore, Skinner, Biscope, Polan, and Golderg (2003) identify that adolescents utilize technology to seek information regarding school, interactions with friends and peer groups, medical conditions, body image and nutrition, violence and safety, and sexual health care. Sixty-seven percent of adolescents polled were interested in seeking health-related information via technology (i.e. the internet) although the quality of the content of the information is not consistently from reputable sources (Skinner et al., 2003).

Despite there being a significant amount of beneficial and resourceful ways to utilize technology, there are some associated risks and concerns. Such risks and concerns include: cyber trolling (bullying), online grooming, pornography, pro-self-harm and eating disorder sites which promote experimentation, isolations, reduced attachment to parents or caregivers, a decline in face-to-face relationships, overreliance, limited connectivity in some graphical areas, privacy and safety, cost, the risk of losing a device, and low literacy and high diversity of users (Barton, 2012; Garrity, 2017; Moawad & Ebrahen, 2016). Regardless of the risks and concerns associated with utilizing technology, adolescents remain keen to explore and make use of technology which may provide benefit to those adolescents diagnosed with T1DM. The following section will discuss the use of technology in health care.

Technology in Health Care

Telemedicine, its approach, application and impact has been studied for over fifty years and continues to evolve. The World Health Organization [WHO] (1997, as cited in WHO 2010) define *telemedicine* as:

> The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment, and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interest of advancing the health of individuals and their communities. (p. 8)

Telemedicine has the potential to improve a patient's health care outcomes and accessibility to health care services while decreasing health care costs (Flodgren, Rachas, Farmer, Inzitari, & Shepperd, 2015). Furthermore, Flodgren et al. (2015) recognize that telemedicine provides a variety of functions, often falling in to one of six categories, associated with the patient's

diagnosis including: monitoring of chronic conditions to assess for the development of complications and to provide rapid treatment and advice, to aid with treatment provisions (including providing cognitive behavioural therapy), for educational purposes in relation to self-management, for specialist consultations and recommendations, for real-time monitoring, and for health care screening.

Modalities utilized to deliver telemedicine services include videoconferencing, telephone contact, downloading glucose values, internet-based education, and connecting health care providers with patients separated by geographical distance (Giani & Laffel, 2016). Telemedicine was the original term used to identify health care services offered from a distance; however, as the popularity of telemedicine increased, the term *telehealth* was introduced to include a wider range of health-related functions including education and administration (Fatehi & Wootton, 2012). A component of telehealth is mHealth which solely utilizes mobile technologies in a health care context and will be discussed in the following section.

mHealth

As the utilization of technology has exponentially increased in the past decade, much of the population now has access to a mobile phone or other type of portable electronic communication device at all times; such devices are capable of conducting tasks and functions not previously possible (Gagnon, Ngangue, Payne-Gagnon, & Desmartis, 2016). The International Telecommunications Union (2015) identified that at the end of 2015 there were more than 7 billion cellular subscriptions worldwide; in 2000, there were 730 million. However, mobile technologies are not limited to mobile phones; other types of mobile devices include: personal digital assistants, smartphones, portable media players, personal video-game consoles, and handheld and portable computers including tablets and laptops (Gagnon et al., 2016). The

functionality of mobile devices varies and can range from messaging, photo and video abilities, telephone and internet access, multimedia playback, tracking and location information, and software application support including the use of applications (apps) (Gagnon et al., 2016).

According to Estrim and Sim, mHealth is recognized as "mobile communication devices, in conjunction with Internet and social media, [that] provide opportunities to enhance disease prevention and management by extending health interventions beyond the reach of traditional care" (2010, p. 759). mHealth technology offers an unconventional method of addressing the challenges of chronic disease management by "enabling remote patient monitoring and delivery of clinical advice through a wide variety of functions (e.g. text messaging, web browsing, email, and videos)" (Kitsiou et al., 2017, para. 2). Furthermore, mHealth can promote health care prevention and health maintenance, aid in monitoring (both short-term and long-term), individualize health care to the specific needs of the patient, detect undesirable incidences and possible complications, and offer interventions and treatment (Varshney, 2005). In the management of adolescents with T1DM, mHealth has the ability to track blood glucose and diet recordings, monitor physical activity, foster education, facilitate self-management and independence, augment patient-provider communication, identify possible complications and provide intervention as necessary, and enhance T1DM-related communication between parents/caregivers and adolescents (Kitsiou et al., 2017). One component of mHealth is applications which will be discussed in the following section.

Applications. Applications (apps) are often a means of providing mHealth; apps are the software installed on a mobile device that can facilitate mHealth. In 2015 the IMS Institute for Healthcare Informatics reported that there are more than 165,000 health-related apps available for Apple iTunes and Android app stores (as cited in Misra, 2015). The function of health-related

apps varies considerably ranging from a basic reminder to apply sunscreen to more sophisticated apps aimed at managing chronic diseases (Boulos, Brewer, Karimkhani, Buller, & Dellavalle, 2014). The diabetes mellitus epidemic is well-reflected in the number of apps available in the management of the chronic disease. Functions of diabetes-targeted apps vary, including: recording blood glucose measures, medication usage recordings (including insulin), and medication dosage calculators. Additionally, some apps can interface with providers as a way in which health information can be shared (for example, blood glucose recordings, dietary intake and physical activity) and to monitor adherence to chronic disease management regimens. Such interactive approaches can provide opportunity for health care professionals to create and adjust a patient's plan of care; however, there are health care provider-related challenges in the literature related to time constraints, usability (i.e. difficulty integrating electronic medical records with apps and problems with overall workflow), resources (i.e. coverage outside of regular working hours), selection of an mHealth system (app) and compensation (Boulos et al., 2014; Mallow et al., 2014; Gray et al.,2016; Gagnon et al., 2016). Since mHealth is highly accessible, Gagnon et al. (2016, para. 3) consider technology as a viable option for professionals in the primary care settings to engage with adolescents diagnosed with T1DM. However, incentives are often offered in research studies with the adolescent population and may be associated with increased usership of mHealth interventions (Afkinich & Blachman-Demner, 2019). Furthermore, there is some association with usability and the inclusion of app end-users in the development and design phases; ideally, end-users are included in these phases (McCurdie et al., 2012).The following section will discuss the role of primary care providers.

Primary Care Providers

Each day, thousands of Canadians visit a primary care provider (PCP) in Canada (Canadian Institute for Health Information [CIHI], 2017). PCPs providing primary care services include both nurse practitioners and family physicians (CIHI, 2017). Furthermore, the services provided by PCPs include: diagnosis; management; treatment and monitoring of acute/episodic and chronic diseases across the lifespan, mental health care, maternity and post-partum care, monitoring of child development, health promotion and disease prevention services, counseling, end-of-life care, referral to specialists and interdisciplinary team members, and minor procedures (CIHI, 2017; Government of Canada, 2012). Accessibility to a primary care provider and an individual's choice to engage is often linked to the health status of an individual (Canadian Nurses Association [CNA], 2015; World Health Organization [WHO], 2019).

The functionality of mHealth can influence health care interactions between patients and PCPs (Gagnon et al., 2016).The monitoring and communication components have capacity for direct patient benefit, including adherence, which may influence long term outcomes. For example, in a systematic review evaluating the effectiveness of mHealth in T1DM and T2DM, Kitsiou et al. (2017) identified that a reduction in HgbA1c was greater when there was a combination of text-messaging and Internet utilization for blood glucose monitoring in addition to clinical feedback. Thus, mHealth may increase monitoring and communication between a PCP and adolescent diagnosed with T1DM which may influence long term outcomes, including HgbA1c. The following section discusses family nurse practitioners in the context of primary care.

Family Nurse Practitioners

Primary care providers include physicians and nurse practitioners in the province of British Columbia. Nurse Practitioners (NPs) were first introduced in British Columbia in 2005 (British Columbia Nurse Practitioner Association [BCNPA], 2005). NPs practice as autonomous professionals providing care to both general and specialized groups, including: marginalized populations with substance use disorder and mental health conditions, seniors, individuals diagnosed with chronic diseases, and individuals with reproductive/women's health concerns (Prodan-Bhalla & Scott, 2017). Additionally, NPs are working in acute care areas, including: trauma, nephrology, gastrointestinal, and cardiac care (Prodan-Bhalla & Scott, 2017, p.8).

Nurse practitioners are regulated health care professionals who obtain additional advanced education in a graduate-level degree in order to diagnose and manage acute and chronic illnesses. NPs are regulated by the British Columbia College of Nursing Professionals [BCCNP], formerly the College of Registered Nurses of British Columbia or CRNBC. In British Columbia, the BCCNP (2018) identifies three streams to categorize areas of NP practice, including: family, adult, and pediatric. Family NPs have the knowledge and ability to provide care to individuals of all ages in primary care settings through the diagnosis, management, and treatment of acute/episodic and chronic conditions and health care screening (BCCNP, 2018). NPs utilize their background in nursing and acquire additional knowledge in health and human sciences to support the diverse needs of their chosen patient population stream. In this context, NPs have the scope of practice and appropriate knowledge and skills to manage T1DM in the adolescent population and may find benefit in utilizing mHealth for chronic disease management in clinical practice.

In summary, background information has been provided to offer context to the presented research question, including: the pathophysiology, clinical presentation, potential complications, HgbA1c and diagnostic criteria, and management of T1DM; adherence of adolescents with T1DM regimens; parental involvement in diabetic management; technology in health care and mHealth; and the role of PCPs. The following section will identify the search strategy that was utilized to obtain and analyze relevant literature to answer the research question. The conceptualization and preliminary search, focused search, and analysis phases will each be discussed in detail.

CHAPTER THREE: METHODS

The objective of this integrative review was to determine if *mHealth, when monitored by a primary care provider, can maintain hemoglobin A1c values in target range with adolescents between the ages of 10-19 with type 1 diabetes mellitus.* The purpose of an integrative review is to analyze concepts in order to gain further understanding and contribute to evidence-based practice (Whittmore & Knafl, 2005). The quality of the methodology of an integrative review may impact the outcome of the posed research question; therefore, it is essential to conduct a focused, comprehensive literature search providing insight of how data was collected and the findings evolved. Providing transparency of the search process identifies possible bias and allows the reader to develop an understanding of the author's progression through the literature (Whittmore & Knafl, 2005). The search strategy, including conceptualization and the preliminary search; the focused search; inclusion and exclusion criteria; and analysis will be discussed in the following section.

Conceptualization and Preliminary Search

The conceptualization of this integrative review is based on five main concepts drawn from reviewing the background literature. These include: the need for more stable metabolic control in adolescents diagnosed with T1DM, the interest that adolescents have in technology, mHealth as an evolving means of monitoring chronic diseases, the possibility of increasing accessibility for PCPs to contact patients and patients to contact PCPs, and an attempt reduce poor diabetic outcomes and complications associated with T1DM.

An initial literature search was conducted in 2015 utilizing Google Scholar to explore the main concepts and connections between adolescence, T1DM, mHealth, and PCPs. Four

electronic databases were then selected to further explore the literature through the University of Northern British Columbia's library:

- the Cumulative Index to Nursing and Allied Health Literature (CINAHL) complete,
- MEDLINE (Ovid)- the US National Library of Medicine's database,
- the National Library of Medicine (PubMed),
- and Cochrane Reviews.

The above databases were selected due to their relevance to health care. The primary search was undertaken in 2015, however the literature search was repeated in 2017 and again in 2018 to ensure up-to-date information could be reviewed as the author had taken a leave from her studies. Dates were limited from 2007 to 2018, in English, and peer-reviewed option-boxes were selected from databases when available; the peer-reviewed option was not an available option for the PubMed, MEDLINE, or Cochrane Reviews databases; however each article selected for this integrative review was peer-reviewed.

To ensure a comprehensive literature review was conducted, key terms and/or medical subject headings (MeSH) with appropriate truncation and wildcard functions were applied (see Table 1). The searches conducted that included the terms "primary care provider" and "primary health care" significantly narrowed the search resulting in zero publications. Modification to the search terms resulted in shifting away from 'primary care provider' to include language which included adolescence. The final search terms included: "adolescent OR adolescence" AND "diabetes mellitus, type 1 OR type 1 diabetes OR T1DM" AND "m?health OR mobile health OR mobile application". In addition to formal academic databases, grey literatures were also reviewed.

More specifically, grey literature relevant to T1DM, mHealth, and PCPs was searched and yielded governmental data and reports from the Public Health Agency of Canada and provincial ministries, statistics from the WHO's, policies and guidelines from the Diabetes Canada (formerly the Canadian Diabetes Association) and the Canadian Paediatric Society, and British Columbia College of Nursing Professional's *Scope of Practice for Nurse Practitioners* document. Lastly, reference lists of publications from the leading researchers in the field of mHealth, T1DM, and adolescents were hand-searched ensuring relevant articles were retrieved and reviewed.

Following the preliminary search, the writer developed a concept map to aid in the conceptualization process, differentiate between similar terms, and to identify connections amongst the terminology (see Appendix A). Burke et al recognize that "… [concept mapping] produces visual representations of the relationship between ideas, which provide unique insight into group thought and perspectives" (2005, p. 1408). Ultimately, the concept map process allowed the writer to confidently identify key terms to utilize in the search process, differentiate between key terms in the field of telemedicine, and make connections between search terms.

Table 1

Search result combinations (conducted June 14, 2018)

Boolean/MeSH Terms		CINAHL	PubMed (no peer review option)	Medline (Ovid) (no peer-review option)	Cochrane Reviews (no peer-review option)
1	Adolescent OR adolescence OR teen* (MeSH: "adolescence", "adolescent")	308,555	680,005	673,186	59,042
2	diabetes mellitus, type 1 OR type 1 diabetes OR T1DM (MeSH: "diabetes mellitus, type 1")	11,830	23,851	24,352	1,774
3	m?health OR mobile health OR mobile application (MeSH: "telehealth", "telemedicine")	4,072	15,112	14,421	2,212
4	Primary care provider OR primary health care provider OR primary health care OR primary care (MeSH: "primary health care")	32,417	41,784	37,781	4,026
1 AND 2		3,583	6,382	6,450	679
1 AND 2 AND 3		7	43	37	11
1 AND 2 AND 4		32	37	32	2
1 AND 3		226	1129	1,108	244
1 AND 4		3,296	5,843	5,176	567
1 AND 2 AND 3 AND 4		0	1	1	0

Focused Search

All articles retrieved utilizing the search result combinations "1 AND 2 AND 3" in Table 1 were then exported into the citation manager Zotero. "Primary Care Provider OR Primary Care OR Primary Healthcare (MeSH: Primary Health Care)" was removed as a primary search

component since the search yielded minimal results when combined with the other key search terms: adolescent, mHealth, and T1DM. Although a few of the articles included in the final literature selection do contain a primary care component or interaction with a health care professional, there was not enough relevant literature available to provide strong evidence to support or refute the research question. Therefore, the primary care component of the research question will be discussed further in the findings and discussion sections.

Furthermore, duplicates were eliminated utilizing Zotero; additional duplicates that the citation management software did not identify were then removed during a hand-search. Titles and abstracts were then screened based on the inclusion and exclusion criteria identified in Table 2. Upon completion of the title and abstract screen, 37 articles remained and were subjected to a full article review. Following the full article screen, application of the inclusion and exclusion criteria, and the removal of two articles as they were opinion papers with no methodology, five articles remained.

Table 2

Inclusion and exclusion criteria for the literature search

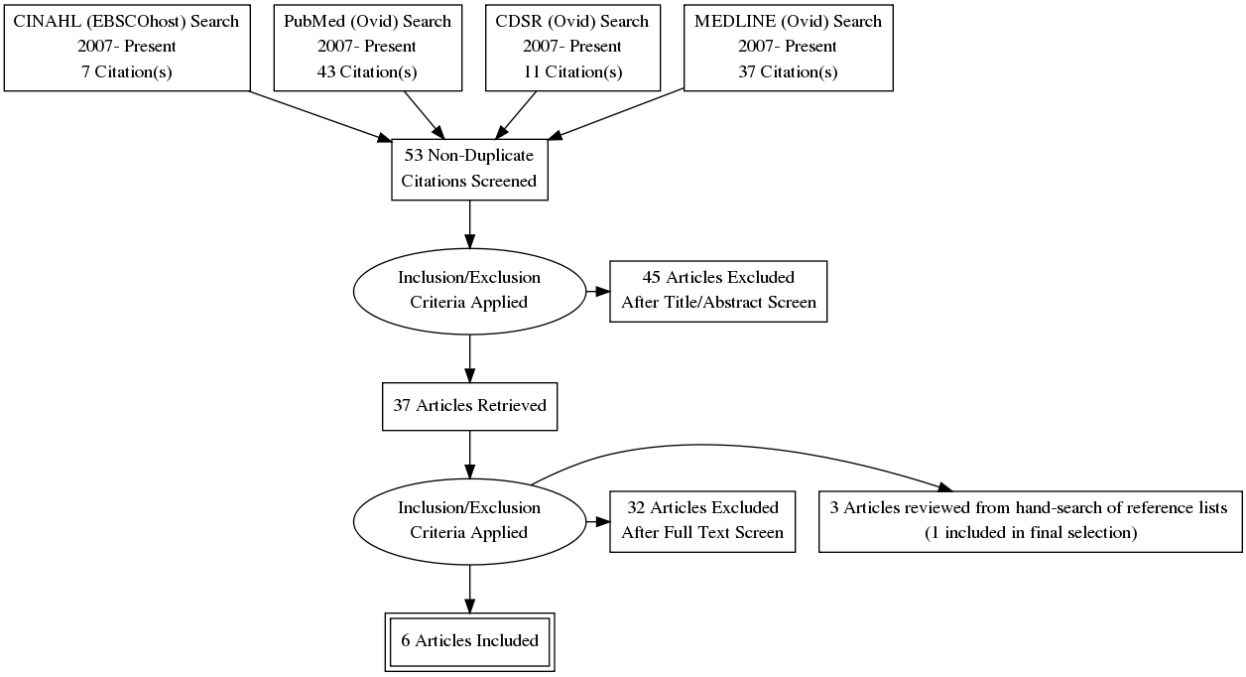
Inclusion Criteria	Exclusion Criteria
-Focus on adolescent patients between the ages of 10-19 -utilization of mHealth technology in the management of T1DM -Monitoring of HgbA1c -Published reports -Years of publication: 2007-2018 -Publication language: English	- Primary focus on adult and pediatric patient populations -Inpatient setting (i.e. acute care) - Blood glucose monitors as the sole mobile technology -Publications older than 10 years -Non-translated reports

References of the remaining articles were also screened to identify relevant literature; one additional article was obtained increasing the total to six. See the PRISMA diagram (Figure 1)

for a visual aid of the search process. Following the review process, a literature matrix was created to assist the writer in organizing relevant data (See Appendix G).

Figure 1

Search strategy and detailed results



Analysis

When reviewing the literature for the research question, a combination of both qualitative studies and quantitative studies presented. As quantitative data utilizes mathematical techniques for measurement in health care research, it can provide relevant data identifying if mHealth technology is effective in maintaining the HgbA1c of adolescents diagnosed with T1DM (Davies & Logan, 2012). The most prevalent quantitative data in this integrative review included statistics related to HgbA1c and participant demographics. However, there was also some qualitative data included in the research studies relevant to evaluating and understanding the

experiences and subsequent thoughts of adolescent patients (and their families) in relation to mHealth, although the qualitative data was limited.

Furthermore, the literature review involved an analysis to examine reliability and credibility of each of the six articles selected. The Joanna Briggs Institute Critical Appraisal Tools were then utilized to assist with this process and evaluate the strengths and limitations of each article. Specific tools included: the JBI Critical Appraisal Checklist for Systematic Reviews and Research Syntheses (Appendix B), the JBI Critical Appraisal Checklist for Quasi-Experimental Studies (Appendix C), the JBI Critical Appraisal Checklist for Qualitative Research (Appendix D), and the JBI Critical Appraisal for Randomized Control Trials (Appendix E). Lastly, a level of evidence rating was assigned to each article guided by the "quality of their design, validity, and applicability to patient care" (Winona State University, 2019, para. 1). The descriptions of the various levels can be found in Appendix F.

This integrative review, including thematic analysis, was guided by Whittemore and Knafl's five stages, including: problem identification, the literature search, data evaluation, data analysis, and presentation (2005, p. 549). Upon analysis of the six articles through data display (creation of a literature matrix), four common themes emerged relevant to post-intervention HgbA1c, including: (1) research design factors (2) technological factors (3) participant factors, and (4) health care provider factors. These themes will be further discussed in the following findings section.

CHAPTER FOUR: FINDINGS

An integrative review was conducted, including: a systematic search of the literature; collecting, reviewing and limiting relevant literature; creating a literature matrix; and finally analyzing, synthesizing, and reporting on the selected articles (Whittemore & Knafl, 2005). Through this process, six articles were selected to guide the research in answering the proposed question; one systematic review (Dougherty et al, 2014), one mixed-methods study (Frøisland et al., 2012), one randomized control trial (DiBartolo et al., 2017), and three quasi-experimental (non-randomized experimental) trials (Cafazzo et al., 2012; Carroll et al., 2011; Mulvaney et al., 2012). The literature matrix in Appendix G provides details of the analysis of the articles selected for this integrative review, including an allocated level of evidence.

Post-Intervention HgbA1c

In each of the articles included in this review, HgbA1c which was used as an objective measurement to quantify the effectiveness of mHealth on glycemic control in adolescents. As HgbA1c is closely monitored in individuals diagnosed with T1DM, each of the selected studies made reference to these values in which the Diabetes Canada guidelines were utilized to identify a target range (Diabetes Canada, 2018). However, none of the selected articles in this integrative review provided strong evidence ($p \leq 0.05$) for the use of mHealth in maintaining HgbA1c amongst the adolescent population. Pre-intervention HgbA1c values amongst the selected articles varied from 8.3 to 11.4% whereas the post-intervention HgbA1c range varied between; increased, reduced, and constant (unchanged) or between 8.1 and 9.79% as per Table 3 (Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Dougherty et al., 2012; Frøisland et al., 2012; Mulvaney et al., 2012). Paired samples *t* tests were most commonly presented to

statistically compare pre and post-intervention HgbA1c values whereas independent *t* tests were calculated to compare HgbA1c values between intervention and control groups Table 3.

Table 3
Pre and post intervention HgbA1c values reporting SD where reported.

Article	Baseline HgbA1c (%)	Post-intervention HgbA1c	Difference in HgbA1c
Cafazzo et al. (2012)	9.2 (SD 1.03)	8.8 (SD 0.74)	-0.4% (p = .11)
Carroll et al. (2011)	8.7	Self-reported (no values documented)	N/A
Di Bartolo et al. (2017)	10 (+/-1.4: 8.6-11.4)	9.66 (+/- 0.13: 9.53-9.79) at 6 months	-0.50 (± 0.14%) (p = .51)
Doughtery et al. (2012)	*varied	*varied	*varied
Frøisland et al. (2012)	8.3 (SD 0.9)	8.1 (SD 0.9)	-0.2% (p = .38)
Mulvaney et al. (2012)	8.8 (SD 2.1- control and intervention groups)	8.8 (SD 2.3- control group; SD 2.1- intervention group)	0 (p = .42)

**= HgbA1c was presented for individual studies included in the review*
SD and p values were included as reported in selected articles

While the answer to the questions of this integrative review is no— mHealth, when monitored by a PCP, does not help adolescents to maintain HgbA1c, other factors emerged for consideration that will be addressed in the discussion section. These include: (1) research design factors, (2) technological factors, (3) participant factors, and (4) health care provider factors. Each theme will be further explored in the following subsections.

Research Design Factors

Two common themes that emerged during analysis related to research design included short intervention periods and small intervention (and control) group sizes. The length of the intervention period and the size of the intervention groups may have affected post-intervention HgbA1c values and will be further reviewed in the following sections.

Short intervention periods. In order for interventional variations to influence HgbA1c, there must be an appropriate intervention time frame as HgbA1c tests long-term control of blood

glucose (accounting for approximately 100 to 120 days prior to the test) (Pagana et al., 2012). A minimum amount of time for the interventional period was considered, although not included as an inclusion criterion for this integrative review as it would have significantly limited the number of studies available. The intervention period ranged from approximately three months or 100 to 120 days (Cafazzo et al., 2012; Frøisland et al., 2012; Mulvaney et al., 2012) to six months or 168 days (Carroll et al., 2011; Di Bartolo et al., 2017); each of the three mHealth-related studies included in Dougherty et al's., systematic review were three months in length. Ultimately, a short intervention period (i.e. three to six months) limits recordable HgbA1c cycles using mHealth apps. Only having one-to-two cycles of HgbA1c measurement during the intervention period limits the collection of reliable data since HgbA1c levels can easily fluctuate when adolescents are managing their T1DM. Additionally, it may have taken users time at the beginning of a study to orientate to and become confident with using the apps. Small intervention group sizes were also identified as a research design factor that affected post-intervention HgbA1c values which, will be discussed in the following subsection.

Small intervention group sizes. Overall the number of participants was small in comparison to the number of adolescents diagnosed with T1DM. Sample sizes between the studies varied significantly, from 12 participants (Carroll et al., 2011; Frøisland et al., 2012) to 182 participants (Di Bartolo et al., 2017). Both Cafazzo et al. (2012) and Mulvaney et al. (2012) had between 20-28 participants. Small interventional groups can impact data; if a participant experiences significant changes to their HgbA1c in a small group, there is a chance that the average (or mean) value in the study could be misrepresented or hyper-inflated/deflated, therefore limiting generalizability.

Recognizing limitations in the studies is a critical aspect of an integrative literature review. Reporting factors which affect post-intervention HgbA1c values can influence future work in this area. Technological factors can also affect post-intervention HgbA1c values which will be reviewed in the following section.

Technological Factors

Each of the studies selected for this integrative review included a unique app designed for adolescents diagnosed with T1DM. However, amongst the selected studies there were extensive variations amongst the apps' functionality. In order to recognize factors that may have contributed to maintaining, improving, or worsening HgbA1c, better understanding of the apps is required. The following section will provide insight into app development and design, the variation in functionality of the apps, technological challenges, and orientation to the app that participants (and often their parents) experienced.

App development and design. Providing the end-users with an opportunity to engage in the app development and design process may be associated with increased user ship of the app. Ideally, end-users are included in the development of an app to provide input for the end-product; however this integrative review recognized that this is not routine practice for apps designed for adolescents diagnosed with T1DM.

Inclusion of adolescents in the app design and development phases varied. Cafazzo et al.'s study collaborated with adolescents and their care providers (parents) during an extensive "user-centered design phase" (2012, p.4). Cafazzo et al. (2012) demonstrated the most inclusive end-user involvement during the development of their *bant* app. However, despite such inclusiveness there was no correlation with post-intervention HgbA1c in comparison to the other studies selected for this integrative review.

For their *SuperEgo* intervention, Mulvaney et al. included "experts in diabetes adherence and clinical care, and adolescents with diabetes" in the design process (2012, p.115). However, Mulvaney et al. (2012) did not disclose if the adolescent participants in the design phase were diagnosed with T1DM, T2DM, or if participants included a combination of both; perhaps because they were considering testing *SuperEgo* with both adolescents with T1DM and adolescents with T2DM.

Information relevant to the design and development of Carroll et al's. *Glucophone* ™ app, Di Bartolo et al's. (2016) *iBGStar* ™ + *DMApp,* and Frøisland et al's. (2012) *Diamob* app were not provided. Additionally, Dougerty et al. (2014) did not include information regarding the development of the apps included in their systematic review.

The development and design phase of an app targeted to be utilized by adolescents with T1DM would ideally involve adolescents diagnosed with T1DM, since they are the end-users. However, many of the studies included in this integrative review did not identify who was included in the early stages of design and development which questions if the targeted end-users, adolescents, were involved in the process and if outcomes of the included studies would have been different had adolescents been involved in the design and development process.

Variation between apps. There were differences amongst the apps' functionality, data management, monitoring parameters, and connectivity with the health care provider. Such differences pose challenges in the clinical setting as health care providers must be able to appraise, select, implement, and evaluate apps in order to utilize them with their patients. Furthermore, the variability in functionality of the apps creates a challenge when comparing the results between the studies. An overview of the apps included in each of the selected studies is presented in Table 4.

Table 4
An Overview of Apps from the Selected Articles

Study	mHealth App	App function
(Cafazzo et al., 2012)	bant	-*bant* received information (blood glucose values) via Bluetooth technology from OneTouch UltraMini glucometers -Alerts provided to remind participants to check their blood glucose -Summaries of daily blood glucose values, meal and activity information, and highlights of out-of-range blood glucose values were provided -Gamification incentives (iTunes gift codes) were provided to encourage the participant to engage with the app -Participants were able to communicate amongst each other via a private group on Twitter
(Carroll et al., 2011)	Glucophone™	-Utilization of cell phone glucose monitoring (CPGM) transmitted SMBG values to a host computer which was monitored by a nurse practitioner (parents also had access to logs) -Additionally, *Glucophone*™ provided the ability to communicate with a nurse practitioner (via phone or text message)
(Di Bartolo et al., 2017)	iBGStar™	-An app used in collaboration with *iBGStar*™ glucose meter -Blood glucose, HgbA1c, quality of life, and the number/type of interactions between the participants and the centre (assumed health care professional, although unidentified) were monitored; information collected was also downloaded during physician visits
(Frøisland et al., 2012)	*Diamob* and Diabetes Message System	-Two mobile phone apps worked together to identify if the apps could impact T1DM disease management -The first app used photos in a diary manner to record physical activity and food consumption in addition to connecting with a glucometer via Bluetooth to track blood glucose values; the second app allowed for protected communication that utilized SMS technology to send messages to health care providers and participants
(Mulvaney et al., 2012)	SuperEgo	-A combined mobile/web-based application targeted at motivating and reminding adolescents of diabetes-related tasks (i.e. SMBG) -Four functions were included in the intervention: assessment, message selection, message scheduling, and requests of messages from other participants; users selected the types of messages they wanted to receive (i.e. in relation to burn out/stress, sports/exercise, etc) in addition to timing and frequency -On average, each participant received 10 messages per week

As evidenced in Table 6 the overall aim of the apps focused on improving glycemic control. The functionality of the apps varied considerably in addition to the presentation and

layout of the apps themselves. For example, several studies (Cafazzo et al., 2012; Carroll et al., 2011; Di Batrolo et al., 2017; Mulvaney et al., 2012) prioritized SMBG in their apps and focused on sending reminders and alerts to participants to check their blood glucose several times a day. Whereas Frøisland et al. (2012) took a different approach and incorporated photography by having participants take a photo of their meal in addition to a pre and post prandial SMBG in order to visualize and connect how diet influences HgbA1c and insulin dosages. The differences in the functionality of the apps create challenges for use in the primary care setting. This point will be further explored in the provider section of the findings.

Technological complications. As technology can fail, identifying potential technological-related complications is imperative to mHealth interventions. Dependable and consistent technology is essential to not only keep participants engaged with mHealth and to reduce frustrations, but also to collect reliable data both clinically and in research. Despite some studies presenting several technological difficulties (i.e. connectivity in rural locations) (Carroll et al., 2011; Frøisland et al. 2012), others experienced fewer difficulties (Cafazzo et al's., 2012; Mulvaney et al., 2011). Of note, the outcomes across all studies were similar in terms of post-intervention HgbA1c, despite technological challenges.

App and device education/orientation. Selected studies provided education on apps function, system and ease of use. Dougherty et al.'s review (2014) acknowledged that research studies which included an app compatible with a participant's existent mobile device were user-friendly. Meaning that, participants who were familiar with their own device and were not required to learn how to use an additional device were less likely to experience a device transition.

How education occurred varied across the studies; all noted training was necessary but details were not consistently provided. For example, Carroll et al. (2011) had a member of the research team sit-down with the adolescent and his or her parent/guardian and provide instruction. Alternatively, Mulvaney et al. (2012) had the adolescent engage in education through automated demonstration. Furthermore, not all studies reported if parents attended app education sessions. Additionally, the amount of time allocated to provide app education to either participants or parents/caregivers was not present in any of the included studies. The following section discusses participant factors relevant to post intervention HgbA1c values in greater detail.

Participant Factors

During the process of analysis, factors specifically related to the participant groups that potentially affected post-intervention HgbA1c were recognized. These included: demographics, incentives, and adherence.

Participant demographics. Several of the articles included in this integrative review provided a variety of demographics specific to their participant population (Cafazzo et al., 2012; Carroll et al., 2011; Dougherty et al., 2014; Frøisland et al., 2012). The eligibility criteria for participants varied between studies, although several consistent demographics were reported including: a minimum amount of time diagnosed with T1DM, age range, the ability to read and write in English, HgbA1c within a specific range, and/or no additional underlying chronic diseases. Two thirds of the studies included minimal socioeconomic and/or background information of selected participants (Cafazzo et al., 2012; Carroll et al., 2011; Dougherty et al., 2014; Frøisland et al., 2012) whereas one third collected a greater depth and range of demographic variables (Di Bartolo et al., 2016; Mulvaney et al., 2012). Comparison between

intervention group and control group was recorded succinctly by Di Bartolo et al., (2016) and included: age, gender, living status, educational and income, clinical disease history and outcome.

Matching within studies aims to improve study efficiency by matching factors such as age. Quantitative approaches aim to improve precision in measurement and analysis meaning that results have greater transferability (Pearce, 2016). Typically, independent variables (the apps) affect the dependent variable (HgbA1c) with confounding factors affecting the independent variable. The only research team that matched their control group to their intervention group was Mulvaney et al. (2012); each group had thirteen males (57 percent), the average age of the intervention group was 15.9 years (15.8 in the control group), and the HgbA1c of participants in both groups was 8.9 percent. Furthermore, of the participants who finished the study, the average amount of time they had been diagnosed with diabetes was 7.9 years, the median household income was $70,000-100,000 annually, and the average age for parental education was 14.3 years.

Providing transparency relevant to patient demographics aids future researchers in better understanding of confounding variables, which may tailor future diabetes management for specific socio-economic groups. For example, there may be a connection between higher socioeconomic status and app usage amongst participants in the intervention groups as households with greater disposable income may have greater opportunity to purchase technology to be able to use apps in their daily lives.

Incentives. Incentives, including access to technology, rewards and compensation, often motivate individuals to engage in a process or complete a specific task that he or she may have not otherwise considered. Incentives may have motivated adolescents to participate and engage

in the studies vs. the app itself (see Appendix G for details of incentives offered in the selected studies). Furthermore, only half of the studies (Cafazzo et al., 2012; Carroll et al., 2011; Frøisland et al., 2012) revealed how participants obtained a device for the duration of the study; of these studies, participants were loaned a smart phone or iPod Touch.

Rewards for using the app were embedded within several studies; for example, the *bant* app had a complex gamification rewards algorithm whereby participants received points for adherence to best-practice guidelines for monitoring of their blood glucose (Cafazzo et al, 2012). Points were provided for each blood glucose test performed and bonus points were allocated for a full day of testing. Participants reported that the ease of attaining the rewards helped motivation since the rewards translated to redeemable vouchers i.e., Apple iTunes and App Store purchases (Cafazzo et al., 2012). Overall, Cafazzo et al. identified that an average of eight rewards per participant was distributed; five of twenty participants collected no rewards and ten percent of participants earned a high number of rewards (2012). Generally, if adolescents collected rewards at the start of the study, they continued accruing rewards until the end of the study. Some participants did not redeem their rewards which raises the question of the importance of incentives for all adolescents. In examining this against sociodemographic data it may have helped identify if motivation to engage in the study was linked to low social-economic status (SES). For example, adolescents from low SES may have enrolled in the study to access otherwise unaffordable monitoring equipment or mobile technology.

Ethical guidelines within many countries outline the maximum financial reward available to participants. Therefore, remuneration of fifty dollars was applied in Carroll et al's. (2011) pilot project, at three study points (at baseline, 3 months, and 6 months) adolescents received

$50. Similarly, Mulvaney et al. (2012) compensated participants although the amount was not disclosed.

Interestingly, none of the studies included in this integrative review identified how incentives or reward approach was determined pre-study. Furthermore, ninety percent of the studies failed to explore participant satisfaction with the incentive or rewards program in the app.

Adherence. Adherence was a recurrent theme that emerged amongst the selected studies and was most commonly measured by participant surveys or in terms of self-monitoring blood glucose (SMBG). Measuring adherence in the adolescent population using HgbA1c alone is ineffective due to physiological changes and other complex factors.

The apps at times appeared to help the youth keep track of their self-care practices, which in turn likely influenced their HgbA1c. For example, Mulvaney et al. identified that their mHealth intervention assisted adolescent participants in "remembering to monitor blood glucose, packing supplies, reducing self-care procrastination, reduced feelings of isolation and embarrassment, and [by] bringing diabetes to 'the front of my [the adolescent's] mind'" suggesting that adherence was improved (2012, p. 117). However, there was no pre or post intervention survey or interview to determine the extent to which adherence improved.

Adherence was linked to the 'type' of app and the creativity in its design. Apps that were able to invite youth to track and monitor their own progress were more successful even if they did not support primary care provider management. For example, Di Bartolo et al. (2014) identified adherence to SMBG monitoring as one of two main objectives in their study determining if their *iBGStar* ^{TM} + *DMApp* apps were superior to traditional blood-glucose monitoring systems. Adherence of SMBG was first assessed two weeks prior to the intervention period by obtaining recorded SMBG data; similar data was then obtained after the intervention

period was complete. Investigators measured and defined adherence in three ways: (1) as a dichotomous variable (i.e. occurrence of SMBG ≥30% vs <30% of the recommended frequency), (2) by the average amount of SMBG conducted weekly, (3) and by "percent compliance" defined as the number of tests performed in comparison to the number of tests prescribed by the adolescent's PCP (Di Bartolo et al., 2014, p. 395). Adherence was again assessed six months following the conclusion of the intervention period which represented Di Bartolo et al's. (2014) primary end points; after six months, 53.6% of individuals in the *iBGStar* ™ + *DMApp* group and 55.0% of individuals in the control group had enhanced SMBG monitoring. While not statistically significant, this supports future study in the area of treatment satisfaction and self-care behaviours. Despite evidence of improvements in self-care practices during the intervention periods, long-term adherence and HgbA1c outcomes remain unknown.

Often self-care is a primary consideration linked to patient outcomes. For example, Cafazzo et al. (2014) measured treatment adherence by conducting a 14 item "Self-Care Inventory" pre and post-intervention survey. The Self-Care Inventory was a self-assessment tool on a scale of 1 (never do it) to 5 (always do this as recommended without fail) (Cafazzo et al., 2014). The Self-Care Inventory did not identify significant changes to pre and post-intervention results; the pre-intervention average score was 3.5 (SD 0.93) whereas the post-intervention average score was 3.6 (SD 0.93) (Cafazzo et al., 2014). However, it should be noted that results from the Self-Care Inventory assessment may be open to bias and they may not capture the patient experiences that are currently influencing self-care.

Similar to Cafazzo et al. (2014), Carroll et al. conducted a self-reported survey using an agree and disagree questionnaire to assess "Adolescent-Reported Activities and Feelings About the Glucophone ™". Sixteen percent of adolescent participants agreed that they increased the

frequency of SMBG as a result of participating in the study (Carroll et al., 2011). However, as the study was self-reported, results need to be considered with caution since the time points to collect data are open to variables such as youth mood, motivation, and other wider factors.

Adherence is a complex factor that is well studied within primary care work. Therefore, the role the primary care provider has in T1DM monitoring, using an app or other approach, is influenced by factors that are attributed to adherence and self-management. The following section will discuss health care provider factors.

Health Care Provider Factors

This integrative review was based on the idea that mHealth monitoring by a primary care provider could maintain HgbA1C in adolescents between 10-19 years. However, not all studies in this review included a primary care provider in their study. This section will discuss the inclusion of a primary care provider in relevant studies in addition to barriers to mHealth implementation in practice.

Inclusion of a primary care provider. The study by Carroll et al., (2011) engaged a nurse practitioner (NP) as the primary care provider within a multi-disciplinary team approach. The role of the NP was valued by the study participants yet did not directly influence HgbA1c outcomes. The term 'value' was not defined in the post-intervention participant survey, however adolescents in Carroll et al.'s (2011) study associated value with accessibility to an NP for chronic disease management support. Communication aspects of the apps were used in studies, such as the messaging the provider, however impact on maintaining HgbA1c levels was not significant (Frøisland et al., 2012). Therefore, despite increasing accessibility and engagement with a health care provider (Carroll et al, 2011; Di Bartolo et al., 2012; Frøisland et al., 2012),

increased accessibility was not linked to improved HgbA1c. Meaning, there was no correlation between time spent engaged with a health care provider and improved or better outcomes.

However, adolescent participants did identify that they appreciated and valued increased access to health care providers. While there was no statistical evidence that health care provider accessibility maintained HgbA1c, there was weak evidence conducted through a post-intervention participant survey to suggest that adolescent-provider interactions reminded adolescents to practice self-care (i.e. SMBG) (Carroll et al., 2011). Despite mHealth not having an effect on post-intervention HgbA1c in this integrative review, there are factors to consider if mHealth was implemented into the practice setting.

Barriers to mHealth implementation in practice. Many health care providers are currently limited by time due to patient demands, a heavy workload, and a national primary care provider shortage in Canada (Malko & Huckfeldt, 2017; Statistics Canada, 2019). When considering mHealth as a means to engage patients and monitor chronic disease, workload and feasibility must be considered. Carroll et al. disclosed that the NP in their study spent an average of two-hours per day communicating with participants regarding flags which included "blood glucose patterns that needed to be addressed to reduce potential acute and chronic problems" (2011, p.61). On average two hours per day were spent updating charts, clinical notes, and dose adjustments while the NP spent an hour in the evening communicating further to adolescents' responses (Carroll et al., 2011). For this reason, Carroll et al. (2011) questioned mHealth's feasibility since the NP in their study worked outside of their normal clinical hours.

Although Frøisland et al. (2012) included two physicians from an outpatient clinic who were responsible for responding to messages from adolescent participants via the Diamob app, they did not indicate the amount of hours per day that the PCPs spent engaging with participants

via Diamob or if the physicians were compensated for their time. Like Frøisland et al. (2012), Di Bartolo et al. (2017) identified that participants made contact with health care professionals at the diabetes centre, however they too did not identify the amount of time that health care professionals were spending contacting participants or if they (the health care professionals) were compensated. Di Bartolo et al. (2017) did acknowledge that their iBGStar™ intervention increased the amount of contact between patients and the diabetes clinic; however they concluded that an increase in contact resulted in increased health care expenditures questioning the feasibility of an mHealth intervention.

Dougherty et al. recognized that studies which combined the utilization of technology with parental and heath care provider involvement were more successful than those that did not (2014). However, Dougherty et al. further identified that clinicians spent time counseling patients, ordering lab work, and adjusting medications via mHealth platforms which was not financially compensated for (2014). Additionally, Dougherty et al. (2014) noted that no intervention from their selected studies was compatible with an electronic health records which would promote provider efficiency; often interventions required multiple logins and manual data entry requiring significant effort. Increased workload from an mHealth initiative without a means for financial compensation would likely result in disinterest from primary care providers; furthermore, the inability for apps to "communicate" with electronic health records and multiple logins could result in provider frustration which would likely lead to dis-engagement from providers. From the studies, the amount of time health care providers needed to understand and apply mHealth was not disclosed. While workload may not directly influence maintaining HgbA1c value, implementing apps in practice requires significant knowledge and time commitment on the part of the primary care provider.

An mHealth intervention is not well-supported from a feasibility and workload point-of-view. Furthermore, compensation, regulation, on-call schedules, etc were negligibly discussed which would only add to costs. The following section will discuss implications for future clinical practice, research, and education.

CHAPTER FIVE: DISCUSSION

The following section focuses on synthesizing key findings, including: research design factors, technological factors, participant factors, and health care provider factors. The objective of this integrative review was to explore if mHealth, when monitored by a primary care provider, could support adolescents with T1DM in maintaining HbgA1c levels; however, as the findings did not support the original hypothesis, it is not recommended. Although, the evidence did uncover considerations for future research and exploration that will be presented here.

Research Design Factors

During analysis of the selected articles, there were two main considerations identified relevant to the studies' research design. These considerations include: short intervention periods and small intervention group sizes which will be further discussed in the following subsections (Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Dougherty et al., 2014; Frøisland et al., 2012; Mulvaney et al., 2012).

Short Intervention Periods

Short interventions periods, i.e. three to six months, limited opportunity for adolescents and health care providers to become familiar with an app and restricted the amount of data available to collect due to the limited number of HgbA1c cycles (Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Dougherty et al., 2014; Frøisland et al., 2012; Mulvaney et al., 2012). Furthermore, as adolescents are situated within a phase of critical development and subsequently, they do not prioritize their health due to compelling psychosocial demands (Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Dougherty et al., 2014; Frøisland et al., 2012; Mulvaney et al., 2012; WHO, 2017). Therefore, while the combination of short intervention periods and app use may help adolescents focus on specific T1DM-related

tasks, using an app to monitor longer term trends of hard endpoints, such as HbgA1c stability, is burdensome for many adolescents. Additional factors that may inhibit longer intervention periods include: time pressures from research studies, challenges engaging adolescents for long periods of time, and participant or parental commitment concerns (Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Dougherty et al., 2014; Frøisland et al., 2012; Mulvaney et al., 2012). It is therefore recommended to increase the duration of studies related to mHealth and HgbA1c monitoring of adolescents diagnosed with T1DM over more than one-to-two HgbA1c cycles.

Small Intervention Group Sizes

Small sample sizes may have been a result of challenges with the recruitment process or a limited population to select participants from (Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Frøisland et al., 2012; Mulvaney et al., 2012). Additionally, adolescents diagnosed with T1DM may not see value in an app making them less inclined to volunteer as participants. Furthermore, as there are many apps available to adolescents, they may be less interested in participating due to app fatigue. As adolescents are 'busy' individuals the extra time demand from a research study may be bothersome or an inconvenience. Lastly, small intervention group size also limits generalizability which affects the ability to apply the study results to a larger population.

Including adolescent participants in research studies is challenging for a range of reasons. Parrish, Duron, and Oxhandler (2017) recognize barriers to recruitment with adolescents such as the complexities of consent and developing cognitive ability and maturity. As adolescents are in the midst of physiological and psychological growth, adolescent maturity is an issue amongst each of the selected studies (Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017;

Dougherty et al., 2014; Frøisland et al., 2012; Mulvaney et al., 2012). In order to reduce research- based recruitment-related challenges in the adolescent population, Grape et al. (2018) suggest the following: follow-up with the potential adolescent of their parent/caregiver as soon as possible after initial contact, focusing on parental engagement and potentially offering an incentive for participation, using multiple methods of communication (i.e. email, text, phone), etc. A combination of the approaches outlined by Grape et al. (2018) were not clearly reported in the reviewed studies only isolated approaches, including incentives and multiple methods of communication (Cafazzo et al., 2012; Carroll et al., 2011; Mulvaney et al., 2012).

Furthermore, small sample sizes limit generalizability. Generalizability is defined as "the extension of research findings and conclusions from a study conducted on a sample population to the population at large. While the dependability of this extension is not absolute, it is statistically probable." (University of Colorado, 2020, para. 2). However, seeking larger intervention group sizes may not be the ultimate answer. Moving away from a quantitative approach towards qualitative research study designs can influence knowledge outputs which in turn can shape and guide practice. For example, Yates and Leggett recognize that "qualitative studies are appropriate for examining relationships between and among variables, describing trends, attitudes, or opinions of a population, as well as for testing the effects of a treatment or intervention on an outcome" (2016, p. 225) which could address some of the current challenges. Qualitative research studies would have a stronger emphasis on the experiences and meaning that adolescents have towards the utilization of mHealth in T1DM management. Future research relevant to mHealth with adolescents would benefit from considering a qualitative research designs, mixed method approached *or* larger intervention group sizes. The following section will discuss technological factors.

Technological Factors

Technological factors relevant to the use of mHealth with adolescents will be discussed in the following section. Such factors include app development and design and technological challenges relevant to app use in the clinical setting.

App Development and Design

Only one third of the articles selected in this integrative review identified modeling a user-centred approach during the development and design phase (Cafazzo et al., 2012; Mulvaney et al., 2012). A user-centred design "involves the user at every stage of the design process" which has been shown to add value to technology and ultimately increase usage (McCurdie et al., 2012, p. 50). The benefits of user-engagement are clear from the literature resulting in increased technology usability and a patient-focused application. Failure to pay attention to involving adolescents can result in poor interest and refusal to use the app ultimately leading to wasted time and development costs (Farinango et al, 2018). The evidence in this review found it would be beneficial to include a user-centred approach during the development and design phase of apps used by adolescents diagnosed with T1DM. If adolescents are ultimately the population that will engage with the app, it would be beneficial to include them during the development and design phases.

Technological Challenges

When utilizing technology, hardware and software challenges can hinder usability and provide frustration for the user. Subsequently, technological challenges can affect the outcome of a research study applying mHealth. For example technology failure or poor connectivity could limit user interface resulting in frustration and disengagement while negatively impacting the study outcome. Although there were technological challenges noted in the selected articles, the

time span of these challenges was not documented; furthermore, there were no technological failures reported (Cafazzo et al., 2012; Carroll et al., 2011; Frøisland et al. 2012; Mulvaney et al., 2011). Depending on the extent of a technological failure and how mHealth technology is being used, patient safety could be compromised. Based on the evidence reviewed, it is recommended that future research explore mHealth back-up strategies.

Participant Factors

Many factors were recognized relevant to participants in the selected studies, including patient demographics, incentives, and adherence. These factors will be synthesized in the following section.

Participant Demographics

Limited demographic reporting in the studies raised questions of equity and diversity. Race, household income, family size, marital status of participant's parents or guardians, etc. were infrequently presented, although Di Bartolo et al. (2016) and Mulvaney et al. (2012) did present a greater detail of demographic information in comparison to the other articles. Robinson, McMichael, and Hernandez suggest that recognizing diversity provides a better understanding of a group's health behaviours, quantifies and monitors outcomes, and reduces disparities meaning that demographic reporting can result in greater insight while eliminating bias (2017, p. 263).

As there has been a substantial amount of attention paid to information and communications technology and access inequalities, it would be beneficial to include these data in research studies (Zhong, 2010, p. 736). For example, adolescents' socioeconomic status is linked to family income; if a family's income is low, the ability to purchase and sustain information technology (i.e. internet connection, app purchases, hardware purchases) is

prohibitive. The evidence related to patient demographics supports three recommendations related to research.

1. Intervention periods should expand over more than one-to-two HgbA1c cycles.
2. Increased number of participants in sample sizes or exploration of qualitative research designs or mixed method approaches in mHealth-related studies.
3. Participant demographics, including socioeconomic status (household income, level of parental education, race, ethnicity, etc.), be presented in the research.

Incentives

Although incentives may engage adolescents to participate in research studies, they question the long-term feasibility of the intervention if participants are motivated solely by the incentive (Carroll et al., 2011; Cafazzo et al., 2012; Mulvaney et al., 2012). Grant and Sugarman state that "incentives are one of the various ways in which people can get other people to do what they want them to do" and although there is a relationship with power, incentives are most often recognized as a form of trade (2010, p. 721). With this idea, the sustainability of mHealth is questioned as it is not feasible to continuously offer mHealth users an incentive. Additionally, who would offer and fund an incentive for mHealth users? Furthermore, the use of incentives to increase adolescent participation is challenging as usership may increase, however it is challenging to recognize genuine interest in an app vs. participation related to the incentive (Grape et al., 2018). The evidence generated within this integrative review suggests that any incentive offered or provided to adolescent participants be clearly identified in the research studies.

Adherence

The findings revealed that there was some evidence to suggest the use of mHealth for improvement to adherence. Adherence amongst adolescents diagnosed with T1DM is complex and multifaceted. Although adherence was mentioned in each article selected for this integrative review, Cafazzo et al. (2012) and Di Bartolo et al. (2017) were the only researchers that closely monitored adherence through self-assessment surveys and pre and post-intervention statistics related to SMBG. As a relationship between adherence to SMBG and a reduction in HgbA1c was identified, future research studying the use of mHealth with adolescents diagnosed with T1DM should shift focus to the relationship between mHealth and adherence using HgbA1c as a subsequent or secondary endpoint (Di Bartolo et al., 2017). Therefore, it is recommended that future research involving mHealth, adolescents, and T1DM include a means of assessing pre and post-intervention adherence. The following section will discuss health care provider factors.

Health Care Provider Factors

Several factors were identified relevant to clinical practice that should be addressed prior to the implementation of mHealth in the clinical setting, including: health care provider education for app appraisal and selection supports, the primary care provider role in mHealth, and provider compensation and on-call scheduling.

Health Care Provider Education for App Appraisal and Selection

Not only does variation amongst apps and devices necessitate education and orientation for adolescents, primary care providers and students utilizing mHealth would also benefit from orientation and education to mHealth applications (Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Doughery et al., 2014; Frøisland et al., 2012; Mulvaney et al., 2012). The risk of a health care provider not understanding the quality of an app may compromise patient

safety (Canadian Medical Association [CMA], 2015). If a primary care provider chose to implement mHealth into their clinical setting to augment traditional chronic disease management, or if a patient requests to engage in mHealth, there are several factors that need to be considered relevant to provider education. The CMA (2015) created a document, "Guiding Principles for Physicians Recommending Mobile Health Applications to Patients", which is targeted towards physicians to assist in the assessment of and clinical application of apps. In addition to having identified that the app is safe and relevant to patient use, a summary of the CMA recommends: ensuring that the app is endorsed by a professional association, medical society, or health care organization; identifying if and when the app requires software updates and recognizing that the app has been time-stamped by the developer at the time of the last update; assessing if the patient has the technological skills to engage with mHealth; informing patients about security risks about mHealth and technology in health care; and recommending apps that have endured validation testing (2015). Each of these recommendations from the CMA (2015) requires a minimum level of knowledge; however it is uncertain where and how providers are to obtain the relevant knowledge to support the safe implementation of apps in the clinical setting.

One example of an organization that aids in assessment of health-related apps is the United Kingdom's Organisation for the Review of Care and Health Applications [ORCHA]. ORCHA evaluates health apps across Europe, the Middle East, Africa, the Americas, and Asia (ORCHA, 2018). ORCHA, or a similar interface, may provide a solution in assisting primary care providers in assessment and recommendation of apps. However, an interface such as ORCHA does hold challenges for primary care providers, including time; the utilization of ORCHA may reduce accessibility for patients to their primary care providers as providers need

time to research the evaluation of health apps. Furthermore, ORCHA has a complex funding model with support from government organizations including the National Health Service, accreditation services offered, hospitals, universities, professional licensure, etc. (ORCHA Health LTD, 2020). Such interfaces may be costly; although ORCHA does not currently have an associated fee for health care providers, this may not be the case in the future. Although ORCHA is one option, reviewing possible systems to aid primary care providers in selecting apps for clinical use is beyond the scope of this integrative review. With numerous chronic disease management apps available, a clear and well-defined process must be established in order for primary care providers (including those who are less technologically inclined) to implement mHealth into clinical practice. For this reason, it is recommended that guidelines or policies be made available to assist primary care providers in app selection for use in the clinical setting.

The Primary Care Provider Role and Organizational Issues in mHealth

The primary care provider role in chronic disease management is pivotal in long-term outcomes of patients (WHO, 2019). Working with adolescents can be challenging for primary care providers yet they have a role in diagnosis, management, treatment and monitoring of acute and chronic diseases; education; and supportive psychosocial development (CIHI, 2017; Government of Canada, 2012). When a health care provider or primary care provider was included in the selected studies, participants valued their support and availability (Carroll et al., 2011; Frøisland et al., 2012). However, often primary care providers are part of a team approach working with adolescents diagnosed with T1DM. Therefore, it is recommended that roles of the interdisciplinary team be further explored to determine who is the most appropriate and cost-effective member to monitor an mHealth intervention (Carroll et al., 2011; Frøisland et al., 2012).

Furthermore, despite participants valuing the presence of a primary care provider or health care provider, organizational matters require consideration, including on-call availability and compensation. Primary care providers have traditionally been required to offer on-call services for health-related issues (Ministry of Health, 2019). Therefore, based on the evidence, it is recommended that on-call schedules and compensation models undergo review when integrating mHealth into clinical practice. The following section will conclude this integrative review.

Conclusion

The prevalence of diabetes has been on the rise in recent years. Subsequently, the amount of diabetes-associated health care expenditure has increased. According to the Government of Canada, approximately 3 million Canadians (8.1%) were living with diagnosed diabetes (T1DM or T2DM) during 2013-2014 amounting to 1 in 300 youth between the ages of 1 and 19 and 1 in 10 adults over the age of 20 (Government of Canada, 2017). By 2026, the Government of Canada predicts that the prevalence of diabetes will increase affecting 14 million Canadians with a cost of five billion dollars annually (2017). As adolescents with T1DM traditionally are often above their glycemic target and non-adherent to treatment regimens, there is value in exploring unconventional treatment adjuncts, such as mHealth.

Guided by the research question, this integrative review explored the literature, identified four common themes from the findings relevant to post-intervention HgbA1c, and synthesized the findings in the discussion section. Although this integrative review does not support the use of mHealth, when monitored by a PCP, to maintain HgbA1c in target range with adolescents between the ages of 10-19 diagnosed with T1DM, recommendations for clinical practice, research, and policy were identified and are presented in Table 4.

Table 4

Summary of Recommendations for Clinical Practice, Education, and Future Research

Recommendations for Clinical Practice	
Recommendation	**Supporting Evidence**
• The use of mHealth with adolescents in clinical practice to maintain HgbA1c, when monitored by a primary care provider, is not supported by the current evidence	• Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Doughery et al., 2014; Frøisland et al., 2012; Mulvaney et al., 2012
• Guidelines and policies be made available to assist primary care providers in app selection for use in the clinical setting	• Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Doughery et al., 2014; Frøisland et al., 2012; Mulvaney et al., 2012
• On-call systems and compensation models for primary care providers relevant to mHealth be reviewed and implemented into practice	• Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Doughery et al., 2014; Frøisland et al., 2012; Mulvaney et al., 2012
Recommendations for Education	
Recommendation	**Supporting Evidence**
• Education relevant to app selection and utilization in clinical practice be implemented for primary care providers and students	• Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Doughery et al., 2014; Frøisland et al., 2012; Mulvaney et al., 2012
Recommendations for Future Research	
Recommendation	**Supporting Evidence**
• Intervention periods of studies including mHealth and HgbA1c expand over more than one-to-two HgbA1c cycles	• Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Frøisland et al., 2012; Mulvaney et al., 2012
• An increase to the number of participants in sample sizes or exploration of qualitative research designs or mixed method approaches in mHealth-related studies	• Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Frøisland et al., 2012; Mulvaney et al., 2012
• Disclosure of participant demographics (including: household income, level of parental education, race, ethnicity, etc.) in mHealth-related research studies	• Di Bartolo et al., 2017; Mulvaney et al., 2012
• Inclusion of end-users in app design and development phases	• Cafazzo et al., 2012; Mulvaney et al., 2012
• Acknowledgement of incentives offered and provided to adolescent research participants	• Cafazzo et al., 2012; Carroll et al., 2011; Di Bartolo et al., 2017; Doughery et al., 2014; Frøisland et al., 2012; Mulvaney et al., 2012
• Measurement of adherence pre and post mHealth intervention documented	• Cafazzo et al., 2012; Di Bartolo et al ., 2017
• Exploration of the most appropriate health care provider to engage in mHealth with adolescents	• Carroll et al., 2011; Di Bartolo et al., 2017; Frøisland et al., 2012
• Exploration of technological back-up strategies for mHealth in clinical practice	• Cafazzo et al., 2012; Frøisland et al., 2012

References

Al-Agha, A., Ocheltree, A., & Hakeem, A. (2011). Metabolic control in children and adolescents with insulin-dependent diabetes mellitus at. *Journal of Clinical Research in Pediatric Endocrinology*, *3*(4), 202–207. http://doi.org/10.4274/jcrpe.415

Afkinich, J. L., & Blachman-Demner, D. R. (2019). Providing incentives to youth participants in research: A literature review. *Journal of Empirical Research on Human Research Ethics*. https://doi.org/10.1177/1556264619892707

American Association for Clinical Chemistry. (2018). *Islet autoantibodies in diabetes*. Retrieved from https://labtestsonline.org/tests/islet-autoantibodies-diabetes

American Diabetes Association. (2018). Children and adolescents: Standards of medical care in diabetes—2018. *Diabetes Care*, *41*(Supplement 1), S126-S136.

American Psychological Association. (2002). *Developing adolescents: A reference guide for professionals*. Retrieved from http://www.apa.org/pi/families/resources/develop.pdf

Anderson, M. & Jiang, J. (2018). *Teens, social media & technology 2018.* Retrieved from http://www.pewinternet.org/2018/05/31/teens-social-media-technology-2018/

Atkinson, M. A., Eisenbarth, G. S., & Michels, A. W. (2014). Type diabetes. *Lancet*, *383*(9911), 69–82. doi: 10.1016/S0140-6736(13)60591-7

Atkinson, M. A., von Herrath, M., Powers, A. C., & Clare-Salzler, M. (2015). Current concepts on the pathogenesis of type 1 diabetes—Considerations for attempts to prevent and reverse the disease. *Diabetes Care, 38*(6), 979-988.

Balasubramanian, K., Dabadghao, P., Bhatia, V., Colman, P. G., Gellert, S. A., Bharadwaj, U., ... & Bhatia, E. (2003). High frequency of type 1B (idiopathic) diabetes in North Indian children with recent-onset diabetes. *Diabetes Care*, *26*(9), 2697-2697.

Barton, A. J. (2012). The regulation of mobile health applications. *BMC medicine*, *10*(1), 46.

BC Children's Hospital. (2016). *Transition timeline brochure.* Retrieved from http://www.bcchildrens.ca/our-services/support-services/transition-to-adult-care

Berg, C. A., King, P. S., Butler, J. M., Pham, P., Palmer, D., & Wiebe, D. J. (2011). Parental involvement and adolescents' diabetes management: The mediating role of self-efficacy and externalizing and internalizing Behaviors. *Journal of Pediatric Psychology*, *36*(3), 329–339. http://doi.org/10.1093/jpepsy/jsq088

Bilandzic, A., & Rosella, L. (2017). The cost of diabetes in Canada over 10 years: Applying attributable health care costs to a diabetes incidence prediction model. *Chronic Diseases and Injuries in Canada*, *37*(2).

Borus, J. S., & Laffel, L. (2010). Adherence challenges in the management of type 1 diabetes in adolescents: Prevention and intervention. *Current opinion in pediatrics*, *22*(4), 405.

Boulos, M. N. K., Brewer, A. C., Karimkhani, C., Buller, D. B., & Dellavalle, R. P. (2014). Mobile medical and health apps: State of the art, concerns, regulatory control and certification. *Online Journal of Public Health Informatics*, *5*(3), 229. http://doi.org/10.5210/ojphi.v5i3.4814

Brashers, V. L., Jones, R. E., & Huether, S. E. (2014). The endocrine system- Alterations of hormonal regulation. In K. L. McCance & S. E. Huether (Eds.), *Pathophysiology- The biologic basis for disease in adults and children* (pp. 717-767). St. Louis, MO: Elsevier.

Brazeau, A. S., Nakhla, M., Wright, M., Panagiotopoulos, C., Pacaud, D., Henderson, M., ... & Dasgupta, K. (2016). Stigma and its impact on glucose control among youth with diabetes: Protocol for a Canada-wide study. *JMIR Research Protocols*, *5*(4).

British Columbia College of Nursing Professionals. (2018). *Scope of practice for nurse practitioners*. Retrieved from https://www.bccnp.ca/Standards/RN_NP /StandardResources/NP_ScopeofPractice.pdf

British Columbia Ministries of Health, Education, and Children and Family Development. (2015). *Provincial standards: Supporting students with type 1 diabetes in the school setting.* Retrieved from http://www2.gov.bc.ca/assets/gov/education/administration/kindergarten-to-grade-12/healthyschools/diabetes/diabetes_support_in_school_settings.pdf

Burke, J. G., O'Campo, P., Peak, G. L., Gielen, A. C., McDonnell, K. A., & Trochim, W. M. (2005). An introduction to concept mapping as a participatory public health research method. *Qualitative Health Research*, *15*(10), 1392-1410.

Butner, J., Berg, C. A., Osborn, P., Butler, J. M., Godri, C., Fortenberry, K. T., … Wiebe, D. J. (2009). Parent-adolescent discrepancies in adolescents' competence and the balance of adolescent autonomy and adolescent and parent well-being in the context of type 1 Diabetes. *Developmental Psychology*, *45*(3), 835–849. doi: 10.1037/a0015363

Caferoğlu, Z., İnanç, N., Hatipoğlu, N., & Kurtoğlu, S. (2016). Health-related quality of life and metabolic control in children and adolescents with type 1 diabetes mellitus. *Journal of Clinical Research in Pediatric Endocrinology*, *8*(1), 67–73. doi: 10.4274/jcrpe.2051

Cafazzo, J. A., Casselman, M., Hamming, N., Katzman, D. K., & Palmert, M. R. (2012). Design of an mHealth app for the self-management of adolescent type 1 diabetes: A pilot study. *Journal of Medical Internet Research*, *14*(3), e70. http://doi.org/10.2196/jmir.2058

Canadian Diabetes Association. (2018). *Diabetes statistics in Canada.* Retrieved from http://www.diabetes.ca/how-you-can-help/advocate/why-federal-leadership-is-essential/diabetes-statistics-in-canada

Canadian Diabetes Association Clinical Practice Guidelines Expert Committee [CDACPGEC]. Canadian diabetes association 2013 clinical practice guidelines for the prevention and management of diabetes in Canada. Canadian Journal of Diabetes 2013; *37*(suppl 1): S1-S212. Retrieved from http://guidelines.diabetes.ca/fullguidelines

Canadian Institute for Health Information. (2017). *Primary health care.* Retrieved from https://www.cihi.ca/en/primary-health-care

Canadian Medical Association. (2015). *Guiding principles for physicians recommending mobile health applications to patients.* Retrieved from https://www.cma.ca/sites/default/files/2018-11/cma_policy_guiding_principles_for_physicians_recommending_mobile_health_applications_to_patients_pd1-e.pdf

Canadian Nurses Association. (2015). *Primary health care.* Retrieved from https://cna-aiic.ca/~/media/cna/page-content/pdf-en/primary-health-care-position-statement.pdf?la=en

Canadian Paediatric Society. (2016). *Age limits and adolescents.* Retrieved from https://www.cps.ca/en/documents/position/age-limits-and-adolescents

Carroll, A. E., DiMeglio, L. A., Stein, S., & Marrero, D. G. (2011). Using a cell phone-based glucose monitoring system for adolescent diabetes management. *The Diabetes Educator, 37*(1), 59-66.

Carroll, A. E., Marrero, D. G., & Downs, S. M. (2007). The HealthPia GlucoPack™ diabetes phone: a usability study. *Diabetes Technology & Therapeutics*, *9*(2), 158-164.

Chiang, J. L., Maahs, D. M., Garvey, K. C., Hood, K. K., Laffel, L. M., Weinzimer, S. A., ... & Schatz, D. (2018). Type 1 diabetes in children and adolescents: A position statement by the American Diabetes Association. *Diabetes Care*, *41*(9), 2026-2044.

Coffen, R. D. (2009). The 600-step program for type 1 diabetes self-management in youth: The magnitude of the self-management task. *Postgraduate medicine*, *121*(5), 119-139.

Contact. (2019). In *Cambridge Dictionary online.* Retrieved from https://dictionary.cambridge.org/dictionary/english/contact

Datye, K. A., Moore, D. J., Russell, W. E., & Jaser, S. S. (2015). A review of adolescent adherence in type 1 diabetes and the untapped potential of diabetes providers to improve outcomes. *Current Diabetes Reports*, *15*(8), 51. doi:10.1007/s11892-015-0621-6

Davies, B. & Logan, J. (2012). Reading research: A user-friendly guide for health professionals (5th ed.). Toronto, ON: Elsevier.

Diabetes Canada. (2018). *Clinical practice guidelines*. Retrieved from https://guidelines.diabetes.ca/cpg

Diabetes Control and Complications Trial Research Group. (1995). The relationship of glycemic exposure (HbA1c) to the risk of development and progression of retinopathy in the diabetes control and complications trial. *Diabetes*, *44*(8), 968-983.

Diabetic Children's Foundation. (2018). T1DM and T2DM. Retrieved from https://www .diabetes-children.ca/en/type-1-diabetes/t1d-t2d/

Di Bartolo, P., Nicolucci, A., Cherubini, V., Iafusco, D., Scardapane, & M., Rossi, M. (2017). Young patients with type 1 diabetes poorly controlled and poorly compliant with self-monitoring of blood glucose: Can technology help? Results of the i-NewTrend randomized clinical trial. *Acta Diabetologica, 54*(4), 393–402.

Distiller, L. A. (2014). Why do some patients with type 1 diabetes live so long?. *World journal of Diabetes*, *5*(3), 282.

Donner, T., Champaneri, S., Saudek, C. (2015). Autoantibodies in type 1 diabetes. *Johns Hopkins Diabetes Guide*. Retrieved from https://labtestsonline.org/tests/islet-autoantibodies-diabetes

Donner, T. (2015). Insulin–pharmacology, therapeutic regimens and principles of intensive insulin therapy. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK278938/

Dougherty, J. P., Lipman, T. H., Hyams, S., & Montgomery, K. A. (2014). Telemedicine for adolescents with type 1 diabetes. *Journal of Nursing Research, 36*(9), 1199–1221. https://doi.org/10.1177/0193945914528387

Dunbar-Jacob, J., & Mortimer-Stephens, M. (2001). Treatment adherence in chronic disease. *Journal of Clinical Epidemiology*, *54*(12), S57-S60.

Estrin, D. & Sim, I. (2010). Open mHealth architecture: An engine for health care innovation. *Science*, *330*(6005), 759-760.

European Patients' Academy. (2018a). *Hard endpoint.* Retrieved from https://www.eupati.eu /glossary/hard-endpoint/

Farinango, C. D., Benavides, J. S., Cerón, J. D., López, D. M., & Álvarez, R. E. (2018). Human-centered design of a personal health record system for metabolic syndrome management based on the ISO 9241-210:2010 standard. *Journal of Multidisciplinary Healthcare*, *11*, 21–37. doi:10.2147/JMDH.S150976

Fatehi, F. & Wootton, R. (2012). Telemedicine, telehealth or e-health? A bibliometric analysis of the trends in the use of these terms. *Journal of Telemedicine and Telecare*, *18*(8), 460-464. doi: 10.1258/jtt.2012.GTH108

Flodgren, G., Rachas, A., Farmer, A. J., Inzitari, M., & Shepperd, S. (2015). Interactive telemedicine: Effects on professional practice and health care outcomes. *The Cochrane Library*.

Frøisland, D. H., Årsand, E., & Skårderud, F. (2012). Improving diabetes care for young people with type 1 diabetes through visual learning on mobile phones: Mixed-methods study. *Journal of Medical Internet Research, 14*(4).

Gagnon, M. P., Ngangue, P., Payne-Gagnon, J., & Desmartis, M. (2016). m-Health adoption by healthcare professionals: A systematic review. *Journal of the American Medical Informatics Association*, *23*(1), 212-220.

Gandhi, K., Vu, B. M. K., Eshtehardi, S. S., Wasserman, R. M., & Hilliard, M. E. (2015). Adherence in adolescents with Type 1 diabetes: Strategies and considerations for assessment in research and practice. *Diabetes Management*, *5*(6), 485.

Garrity, V. (2017). Tweens, teens, and technology: The risks and the benefits. *The Association for Child and Adolescent Mental Health.* Retrieved from https://www.acamh.org/blog/tweens-teens-technology-risks-benefits/

Giani, E. & Laffel, L. (2016). Opportunities and challenges of telemedicine: Observations from the wild west in pediatric type 1 diabetes. *Diabetes Technology & Therapeutics*,*18*(1), 1-3.

Government of Alberta. (2020). *Glycohemoglobin (HgbA1c, A1c).* Retrieved from https://myhealth.alberta.ca/Health/Pages/conditions.aspx?hwid=hw8432

Government of Canada. (2012). *About primary health care.* Retrieved from https://www .canada.ca/en/health-canada/services/primary-health-care/about-primary-health-care.html

Government of Canada. (2017). *Diabetes in Canada.* Retrieved from https://www.canada.ca/en /public-health/services/publications/diseases-conditions/diabetes-canada-highlights-chronic-disease-surveillance-system.html#box1

Grant, R. W. & Sugarman, J. (2010). Ethics in human research: Do incentives matter. *Journal of Medicine and Philosophy, 29*(6), 717-738.

Grape, A., Rhee, H., Wicks, M., Tumiel-Berhalter, L., & Sloand, E. (2018). Recruitment and retention strategies for an urban adolescent study: Lessons learned from a multi-center study of community-based asthma self-management intervention for adolescents. *Journal of Adolescence*, *65*, 123–132. https://doi.org/10.1016/j.adolescence.2018.03.004

Gray, C. S., Gill, A., Khan, A. I., Hans, P. K., Kuluski, K., & Cott, C. (2016). The electronic patient reported outcome tool: Testing usability and feasibility of a mobile app and portal to support care for patients with complex chronic disease and disability in primary care settings. *Journal of Medical Internet Research*, *4*(2), e58.

Hamine, S., Gerth-Guyette, E., Faulx, D., Green, B. B., & Ginsburg, A. S. (2015). Impact of mHealth chronic disease management on treatment adherence and patient outcomes: A systematic review. *Journal of Medical Internet Research*, *17*(2), e52.

HealthLinkBC. (2018). *Glycohemoglobin (HbA1c, A1c).* Retrieved from https://www.healthlinkbc.ca/medical-tests/hw8432

Herge, W. M., Streisand, R., Chen, R., Holmes, C., Kumar, A., & Mackey, E. R. (2012). Family and youth factors associated with health beliefs and health outcomes in youth with type 1 diabetes. *Journal of Pediatric Psychology*, *37*(9), 980–989. http://doi.org/10.1093/jpepsy /jss067

Horne, R., Weinman, J., Barber, N., Elliott, R., Morgan, M., Cribb, A., & Kellar, I. (2005). Concordance, adherence and compliance in medicine taking. London, EN*: NCCSDO*, *2005*, 40-6.

International Telecommunications Union. (2015). *ICT facts and figures: The world in 2015.* Retrieved from https://www.itu.int/en/ITU-D/Statistics/Documents/facts /ICTFactsFigures2015 .pdf

Jeha, G. S. & Haymond, M. W. (2016). Clinical features and diagnosis of diabetic ketoacidosis in children. In J. I. Wolfsdorf & A. G. Hoppin (Eds.), *UpToDate.* Waltham, Mass.: UpToDate. Retrieved from www.uptodate.com

Joanna Briggs Institute. (2017a). *Checklist for systematic reviews and research syntheses.* Retrieved from http://joannabriggs.org/assets/docs/critical-appraisal-tools/JBI_Critical _Appraisal-Checklist_for_Systematic_Reviews2017.pdf

Joanna Briggs Institute. (2017b). *Checklist for quasi-experimental studies.* Retrieved from http://joannabriggs.org/assets/docs/critical-appraisal-tools/JBI_Quasi-Experimental _Appraisal_Tool2017.pdf

Joanna Briggs Institute. (2017c). *Checklist for qualitative research.* Retrieved from http://joannabriggs.org/assets/docs/critical-appraisal-tools/JBI_Critical_Appraisal-Checklist_for_Qualitative_Research2017.pdf

Joanna Briggs Institute. (2017d). *Checklist for randomized control trials.* Retrieved from http://joannabriggs.org/assets/docs/critical-appraisal-tools/JBI_RCTs_Appraisal_tool2017.pdf

Johnson, M. (2015). The online lives of Canadian youth. *The Vanier Institute of the Family.* Retrieved from https://vanierinstitute.ca/online-lives-canadian-youth/

Juarez, D., Goo, R., Tokumaru, S., Sentell, T., Davis, J., & Mau, M. (2013). Association between sustained glycated hemoglobin control and healthcare costs. *The American Journal of Pharmacy Benefits*, *5*(2), 59–64.

Kalyani, R. R. (2017). Diagnosis and classification of diabetes. *John Hopkins Diabetes Guide.* Retrieved from https://www.hopkinsguides.com/hopkins/view/Johns_Hopkins_Diabetes_Guide/547038/all/Diagnosis_and_Classification_of_Diabetes

Kitsiou, S., Paré, G., Jaana, M., & Gerber, B. (2017). Effectiveness of mHealth interventions for patients with diabetes: An overview of systematic reviews. *Public Library of Science One*, *12*(3), e0173160. doi: 10.1371/journal.pone.0173160

Lenhart, A. (2015). *Teens, social media & technology: Overview 2015.* Retrieved from http://www.pewinternet.org/2015/04/09/teens-social-media-technology-2015/

Litmanovitch, E., Geva, R., & Rachmiel, M. (2015). Short and long term neuro-behavioral alterations in type 1 diabetes mellitus pediatric population. *World Journal of Diabetes*, *6*(2), 259–270. http://doi.org/10.4239/wjd.v6.i2.259

Malko, A. V., & Huckfeldt, V. (2017). Physician shortage in Canada: A review of contributing factors. *Global Journal of Health Science*, *9*(9), 68-80.

Mallow, J.A., Theeke, L. A., Barnes, E. R., Whetsel, T., & Mallow, B. K. (2014) Using mHealth tools to improve rural diabetes care guided by the chronic care model. *Online Journal of Rural Nursing & Health Care, 14*(1), 43-65. doi:10.14574 /ojrnhc.v14i1.276

Marshall, M., Carter, B., Rose, K., & Brotherton, A. (2009). Living with type 1 diabetes: Perceptions of children and their parents. *Journal of Clinical Nursing*, *18*(12), 1703-1710.

Masharani, U. (2016). Diabetes mellitus & hypoglycemia. In M. A. McCance & S. J. McPhee (Eds.). *Current-Medical diagnosis and treatment* (pp. 1190-1248). United States of America: McGraw-Hill.

McCurdie, T., Taneva, S., Casselman, M., Yeung, M., McDaniel, C., Ho, W., & Cafazzo, J. (2012). mHealth consumer apps: The case for user-centered design. *Biomedical Instrumentation & Technology*, *46*(s2), 49-56.

Medical Dictionary. (2017). In *Merriam Webster online*. Retrieved April 18, 2017, from https://medlineplus.gov/mplusdictionary.html

Metzger, D. L. (2010). Diabetic ketoacidosis in children and adolescents: an update and revised treatment protocol. *BC Medical Journal*, *52*, 24-31.

Ministries of Health, Education and Children and Family Development. (2015). *Provincial standards: Supporting students with type 1 diabetes in the school setting.* Retrieved from http://www.bcchildrens.ca/SHHC-Your-Visit-Site/Documents/Supporting_Students_with _Type_1 _Diabetes _School_Setting.pdf

Misra, R. (2015). *New report finds more than 165,000 mobile health apps now available, takes close look at characteristics & use*. Retrieved from http://www.imedicalapps.com/2015/09/ims-health-apps-report/

Moawad, G. E., & Ebrahem, G. G. S. (2016). The relationship between use of technology and parent-adolescents social relationship. *Journal of Education and Practice*, *7*(14), 168-178.

Moore, S. M., Hackworth, N. J., Hamilton, V. E., Northam, E. P., & Cameron, F. J. (2013). Adolescents with type 1 diabetes: Parental perceptions of child health and family functioning and their relationship to adolescent metabolic control. *Health and Quality of Life Outcomes*, *11*, 50. http://doi.org/10.1186/1477-7525-11-50

Mulvaney, S. A., Anders, S., Smith, A. K., Pittel, E. J., & Johnson, K. B. (2012). A pilot test of a tailored mobile and web-based diabetes messaging system for adolescents. *Journal of Telemedicine, 18*(2), 115–118. https://doi.org/10.1258/jtt.2011.111006

Nathan, D. M. (2014). The diabetes control and complications trial/epidemiology of diabetes interventions and complications study at 30 years: Overview. *Diabetes Care*, *37*(1), 9-16.

National Health Service. (2017). *Diabetic ketoacidosis.* Retrieved from https://www.nhs.uk/conditions/diabetic-ketoacidosis/

ORCHA Health LTD. (2020). ORCHA- Digital health products & services. *Organisation for the Review of Care and Health-Related Apps.*

Organisation for the Review of Care and Health Applications. (2018). *About us.* Retrieved from https://www.orcha.co.uk/about-us/

Pagana, K. D., Pagana, T. J., & Pike-MacDonald, S. A. (2012). *Mosby's Canadian Manual of Diagnostic and Laboratory Tests*. Milton, ON: Elsevier Canada.

Papadakis, M. A., & McPhee, S. J. (Eds.). (2016). *CURRENT medical diagnosis and treatment*. New York, NY: McGraw Hill.

Paschou, S. A., Papadopoulou-Marketou, N., Chrousos, G. P., & Kanaka-Gantenbein, C. (2018). On type 1 diabetes mellitus pathogenesis. *Endocrine Connections, 7*(1), R38-R46.

Paterick, T. E., Patel, N., Tajik, A. J., & Chandrasekaran, K. (2017). Improving health outcomes through patient education and partnerships with patients. *Proceedings*, *30*(1), 112.

Pearce, N. (2016). Analysis of matched case-control studies. *British Medical Journal*, *352*, i969.

Prodan-Bhalla, N. & Scott, L. (2017). *Primary care transformation in British Columbia:* A new model to integrate nurse practitioners. *British Columbia Nurse Practitioner Association.* Retrieved from https://bcnpa.org/wp-content/uploads/BCNPA_PHC_Model_FINAL -November-2-2016.pdf

Provincial Health Services Authority. (2017). *Diabetes.* Retrieved from http://www.bcchildrens.ca/health-info/coping-support/diabetes

Public Health Agency of Canada. (2011). *Diabetes in Canada: Facts and figures from a public health perspective.* Retrieved from http://www.phac-aspc.gc.ca/cd-mc/publications/diabetes -diabete/facts-figures-faits-chiffres-2011/pdf/facts-figures-faits-chiffres-eng.pdf

Robinson, J. K., McMichael, A. J., & Hernandez, C. (2017). Transparent reporting of demographic characteristics of study participants. *JAMA Dermatology*, *153*(3), 263-264.

Saberzadeh-Ardestani, B., Karamzadeh, R., Basiri, M., Hajizadeh-Saffar, E., Farhadi, A., Shapiro, A. J., ... & Baharvand, H. (2018). Type 1 Diabetes Mellitus: Cellular and molecular pathophysiology at a Glance. *Cell journal*, *20*(3), 294-301.

Skinner, H., Biscope, S., Poland, B., & Goldberg, E. (2003). How adolescents use technology for health information: implications for health professionals from focus group studies. *Journal of Medical Internet Research*, *5*(4), e32.

Smaldone, A., Steiner, R., & Whittemore, B. (2017). Endocrine and metabolic disorders. In C. E. Burns, A. M. Dunn., M. A. Brady., N. B. Starr, C. G. Blosser, & D. L. Garzon (Eds.), *Pediatric primary care* (6th ed., pp. 596-625). St. Louis, MO: Elsevier.

Smith, J., Cheater, F., & Bekker, H. (2015). Parents' experiences of living with a child with a long-term condition: A rapid structured review of the literature. *Health Expectations*, *18*(4), 452-474.

Statistics Canada. (2019). *Primary health care providers, 2017.* Retrieved from https://www150.statcan.gc.ca/n1/pub/82-625-x/2019001/article/00001-eng.htm

Taddeo, D., Egedy, M., & Frappier, J.-Y. (2008). Adherence to treatment in adolescents. *Paediatrics & Child Health, 13*(1), 19–24.

US National Library of Medicine. (2018). *Osmotic diuresis.* Retrieved from https://medlineplus.gov/ency/article/001266.htm

Varshney, U. (2005). Pervasive healthcare: applications, challenges and wireless solutions. *Communications of the Association for Information Systems*, *16*(1), 3.

van de Kar, E., & Den Hengst, M. (2009). Involving users early on in the design process: Closing the gap between mobile information services and their users. *Electronic Markets*, *19*(1), 31-42.

Viswanathan, M., Golin, C. E., Jones, C. D., Ashok, M., Blalock, S. J., Wines, R. C., ... & Lohr, K. N. (2012). Interventions to improve adherence to self-administered medications for chronic diseases in the United States: A systematic review. *Annals of Internal Medicine*, *157*(11), 785-795.

Venes, D. (Ed.). (2001). *Taber's cyclopedic medical dictionary.* Philadelphia, PA: FA Davis.

Wallander, J. L., & Varni, J. W. (1998). Effects of pediatric chronic physical disorders on child and family adjustment. *Journal of Child Psychology and Psychiatry*, *39*(1), 29-46.

Watanabe, J. H., McInnis, T., & Hirsch, J. D. (2018). Cost of prescription drug–related morbidity and mortality. *Annals of Pharmacotherapy*, *52*(9), 829-837.

Wherrett, D., Huot, C., Mitchell, B., & Pacaud, D. (2013). Diabetes Canada clinical practice guidelines 2013: *Type 1 diabetes in children and adolescents.* Retrieved from http://guidelines.diabetes.ca/browse/chapter34

Wherrett, D., Ho, J., Huot, C., Legault, L., Nakhla, M., & Rosolowsky, E. (2018). 2018 Clinical practice guidelines: Type 1 diabetes in children and adolescents. *Canadian Journal of Diabetes*, *42*(Suppl 1), S234-246.

Whittemore, R., & Knafl, K. (2005). The integrative review: Updated methodology. *Journal of Advanced Nursing, 52*(5), 546-553. doi:10.1111/j.1365-2648.2005.03621.x

Winona State University. (2019). *Evidence based practice toolkit.* Retrieved from https://libguides.winona.edu/c.php?g=11614&p=61584

World Health Organization. (2003). *Adherence to long-term therapies: Evidence for action.* Retrieved from http://www.who.int/hiv/pub/prev_care/lttherapies/en/

World Health Organization. (2010). *Telemedicine: Opportunities and developments in member states.* Retrieved from http://www.who.int/goe/publications/goe_telemedicine_2010.pdf

World Health Organization. (2017). *Adolescent development.* Retrieved from http://www.who.int/maternal_child_adolescent/topics/adolescence/development/en/

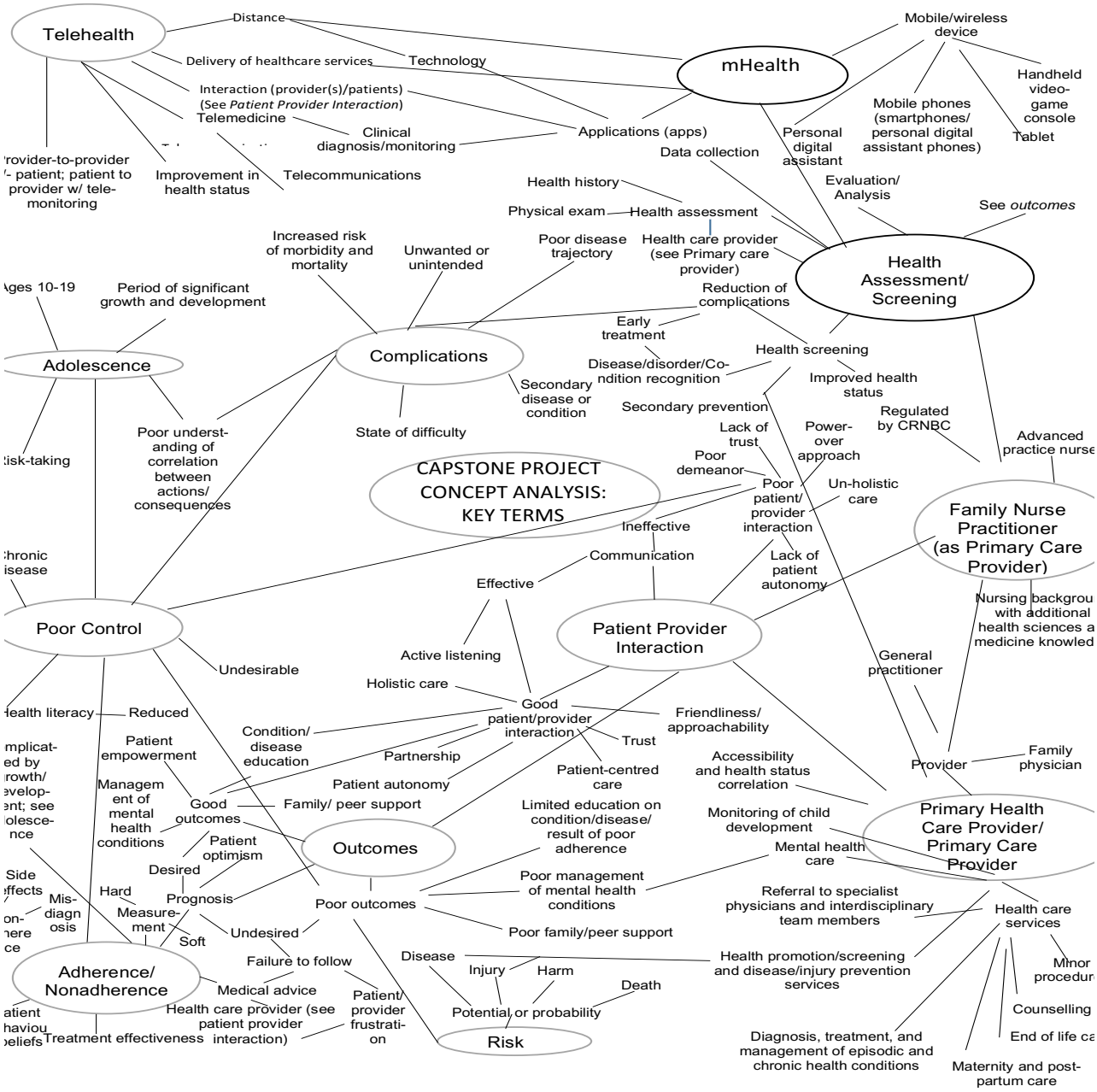
World Health Organization. (2019). *Primary health care.* Retrieved from https://www.who.int/news-room/fact-sheets/detail/primary-health-care

You, W. P., & Henneberg, M. (2016). Type 1 diabetes prevalence increasing globally and regionally: The role of natural selection and life expectancy at birth. *BMJ Open Diabetes Research & Care*, *4*(1), 1-7. doi: 10.1136/bmjdrc-2015-000161

Zhong, Z. J. (2011). From access to usage: The divide of self-reported digital skills among adolescents. *Computers & Education*, *56*(3), 736-746.

Appendix A

Concept Map



Appendix B

JBI Critical Appraisal Checklist for Systematic Reviews and Research Syntheses

Reviewer_____Date_____
Author _____Year_____Record Number_____

		Yes	No	Unclear	Not applicable
1.	Is the review question clearly and explicitly stated?	☐	☐	☐	☐
2.	Were the inclusion criteria appropriate for the review question?	☐	☐	☐	☐
3.	Was the search strategy appropriate?	☐	☐	☐	☐
4.	Were the sources and resources used to search for studies adequate?	☐	☐	☐	☐
5.	Were the criteria for appraising studies appropriate?	☐	☐	☐	☐
6.	Was critical appraisal conducted by two or more reviewers independently?	☐	☐	☐	☐
7.	Were there methods to minimize errors in data extraction?	☐	☐	☐	☐
8.	Were the methods used to combine studies appropriate?	☐	☐	☐	☐
9.	Was the likelihood of publication bias assessed?	☐	☐	☐	☐
10.	Were recommendations for policy and/or practice supported by the reported data?	☐	☐	☐	☐
11.	Were the specific directives for new research appropriate?	☐	☐	☐	☐

Overall appraisal: Include ☐ Exclude ☐ Seek further info ☐

Comments (Including reason for exclusion)
(Joanna Briggs Institute [JBI], 2017a)

Appendix C

JBI Critical Appraisal Checklist for Quasi-Experimental Studies

(non-randomized experimental studies)

Reviewer_____Date_____

Author _____Year_____Record Number_____

		Yes	No	Unclear	Not applicable
1.	Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)?	☐	☐	☐	☐
2.	Were the participants included in any comparisons similar?	☐	☐	☐	☐
3.	Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	☐	☐	☐	☐
4.	Was there a control group?	☐	☐	☐	☐
5.	Were there multiple measurements of the outcome both pre and post the intervention/exposure?	☐	☐	☐	☐
6.	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	☐	☐	☐	☐
7.	Were the outcomes of participants included in any comparisons measured in the same way?	☐	☐	☐	☐
8.	Were outcomes measured in a reliable way?	☐	☐	☐	☐
9.	Was appropriate statistical analysis used?	☐	☐	☐	☐

Overall appraisal: Include □ Exclude □ Seek further info □

Comments (Including reason for exclusion)

(JBI, 2017b)

Appendix D

JBI Critical Appraisal Checklist for Qualitative Research

Reviewer_____Date_____.

Author _____Year_____Record Number _____.

	Yes	No	Unclear	Not applicable
12. Is there congruity between the stated philosophical perspective and the research methodology?	☐	☐	☐	☐
13. Is there congruity between the research methodology and the research question or objectives?	☐	☐	☐	☐
14. Is there congruity between the research methodology and the methods used to collect data?	☐	☐	☐	☐
15. Is there congruity between the research methodology and the representation and analysis of data?	☐	☐	☐	☐
16. Is there congruity between the research methodology and the interpretation of results?	☐	☐	☐	☐
17. Is there a statement locating the researcher culturally or theoretically?	☐	☐	☐	☐
18. Is the influence of the researcher on the research, and vice- versa, addressed?	☐	☐	☐	☐
19. Are participants, and their voices, adequately represented?	☐	☐	☐	☐
20. Is the research ethical according to current criteria or, for recent studies, and is there evidence of ethical approval by an appropriate body?	☐	☐	☐	☐
21. Do the conclusions drawn in the research report flow from the analysis, or interpretation, of the data?	☐	☐	☐	☐

Overall appraisal: Include ☐ Exclude ☐ Seek further info ☐

Comments (Including reason for exclusion)

(JBI, 2017c)

Appendix E

JBI Critical Appraisal Checklist for Randomized Controlled Trials

Reviewer_____Date_____

Author _____Year_____Record Number

	Yes	No	Unclear	NA
22. Was true randomization used for assignment of participants to treatment groups?	☐	☐	☐	☐
23. Was allocation to treatment groups concealed?	☐	☐	☐	☐
24. Were treatment groups similar at the baseline?	☐	☐	☐	☐
25. Were participants blind to treatment assignment?	☐	☐	☐	☐
26. Were those delivering treatment blind to treatment assignment?	☐	☐	☐	☐
27. Were outcomes assessors blind to treatment assignment?	☐	☐	☐	☐
28. Were treatment groups treated identically other than the intervention of interest?	☐	☐	☐	☐
29. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	☐	☐	☐	☐
30. Were participants analyzed in the groups to which they were randomized?	☐	☐	☐	☐
31. Were outcomes measured in the same way for treatment groups?	☐	☐	☐	☐
32. Were outcomes measured in a reliable way?	☐	☐	☐	☐
33. Was appropriate statistical analysis used?	☐	☐	☐	☐
34. Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?	☐	☐	☐	☐

Overall appraisal: Include □ Exclude □ Seek further info □

Comments (Including reason for exclusion)

(JBI, 2017d)

Appendix F

Level of Evidence

Level of evidence (LOE)	Description
Level I	Evidence from a systematic review or meta-analysis of all relevant RCTs (randomized controlled trial) or evidence-based clinical practice guidelines based on systematic reviews of RCTs or three or more RCTs of good quality that have similar results.
Level II	Evidence obtained from at least one well-designed RCT (e.g. large multi-site RCT).
Level III	Evidence obtained from well-designed controlled trials without randomizations (i.e. quasi-experimental).
Level IV	Evidence from well-designed case-control or cohort studies.
Level V	Evidence from systematic reviews of descriptive and qualitative studies (meta-synthesis).
Level VI	Evidence from a single descriptive or qualitative study.
Level VII	Evidence from the opinion of authorities and/or reports of expert committees.

(Ackley, Swan, Ladwig, & Tucker as cited in Winona State University, 2019)

Appendix G

Literature Matrix

Author/Title/Overview/Design	Strengths	Limitations	Significant Findings
(Cafazzo et al., 2012) **Title:** Design of an mHealth App for the Self-management of Adolescent Type 1 Diabetes: A Pilot Study Quasi-experimental (non-randomized experimental)/pilot study. Level of Evidence: Level III N= 20 Adolescents (ages 12-16 years; mean 14.9) diagnosed with T1DM and their caregivers were interviewed and data was collected to inform the production of a mobile application, Bant. 15 participants provided with an iPhone 4 and 5 participants were provided with an iPod Touch (to	Canadian study (adolescents recruited from the Hospital for Sick Children in Toronto, ON). Treatment adherence, quality of life, self-care behaviours, and parent-adolescent interactions regarding T1DM were also examined (in addition to HgbA1c). Adolescents and their parents were interviewed (separately) during the design and clinical pilot phases.	Small sample size of 20 participants. Length of study 12 weeks. No control group. Tension reported between the tester/collector and analyst/decision maker however details not available—could this have affected study results? Gamification rewards (iTunes redemption codes) is not sustainable long-term and may have influenced results of study.	No significant changes of HgbA1c during duration of the study (9.2% pre-intervention (SD 1.03), 8.8% post-intervention (SD 0.74); p=0.11). The average daily frequency of blood glucose testing increased 50% (from 2.4 to 3.6 times per day; P= 0.006). Mild improvement between adolescent and parent communication re. T1DM pre-intervention/post-intervention. Survey results from the *Diabetes Quality of Life (QoL) Instrument for Youth* identified no change or a slighty worse change to QoL pre/post intervention. 14/16 participants identified that they would continue using the application.

test if availability of WiFi altered the user's experience). Gamification incorporated into app; rewards earned when the adolescent adhered to T1DM best-practice guidelines. Bant app data could be viewed by parents' adolescents online via TELUS health space.	Participants were varied in their insulin administration method; 9 used an insulin pump and 11 administered via injection multiple times per day. Limitations identified.		The authors suggest that telemedicine in conjunction with self-monitoring of blood glucose may only be beneficial when there is an educational of behavioural advice component which may yield changes to the individual's clinical management. mHealth well-received by participant's schools.
(Carroll et al., 2011) **Title:** Using a cell phone-based glucose monitoring system for adolescent diabetes management. Quasi-experimental (non-randomized experimental)/pilot study. Level of evidence: Level III N= 40 A *Glucophone,* a cell phone glucose monitoring system, was developed to send blood glucose values to a computer that was monitored by an NP. The NP was then able to make adjustments to	Includes both adolescent and parent perspectives. Near-balanced ratio of male-to-female participants (19 females, 20 males). The study provided compensation ($50 per survey (3 surveys in total)) and the integrated cellphone/glucose meter reducing socioeconomic status as a barrier to participation in the study.	Study conducted over 6 months. Small sample size- 40 participants recruited. Technological difficulties were significant and may have compromised results. No control group.	Parents and adolescents valued the inclusion of an NP. Average baseline HgbA1c was 8.7; 60% of adolescents and 46% of parents agreed that the HgbA1c had decreased during the study however the information was self-reported. The majority of participants reported increased independence in their diabetic management due to the Glucophone. 80% of parents of participants at-ease with their son/daughter's diabetic management; 66% believed their adolescent's health benefited from the intervention.

insulin regimens, discuss blood glucose values, or make a referral with the adolescent and her/his parents (as needed) via text message (if no response was made, the NP initiated a phone call).			Feasibility is questioned as the NP was working outside of normal office hours.
(Di Bartolo et al., 2017) **Title:** Young patients with type 1 diabetes poorly controlled and poorly compliant with self-monitoring of blood glucose: Can technology help? Results of the i-NewTrend randomized clinical trial. Randomized control trial comparing experimental blood glucose monitoring with mHealth to a traditional SMBG. Level of evidence: Level II N= 182	182 participants; 90 in the Control Group, 92 in the experimental group. 168 patients completed the study. Randomization achieved through sealed envelopes. Thorough statistical analysis.	Study conducted over 6 months. Socioeconomic status unidentified; were cellular devices provided or did patients have access to a device for the study?	HgbA1c changes from the 1st month to the 12th month: −0.50 ± 0.14% in iBGStar and −0.63 ± 0.14% in Control (p = 0.64). Includes quality of life component. Concludes that telemedicine can increase SMBG compliance, increased frequency of SMBG testing may contribute to HgbA1c, few participants in the experimental group utilized the full potential of the technology available therefore it becomes a challenge to identify the complete technological benefits, and telemedicine may increase health care expenditure. No PCP component.

(Dougherty et al., 2014) **Title:** Telemedicine for Adolescents with Type 1 Diabetes Systematic review yielding 15 studies. Inclusion criteria included: majority age of the population between 13 and 18 years, T1DM, English language, telemedicine intervention (studies excluded if telemedicine was not the sole intervention), and evaluation of HgbA1c. Level of evidence: I N= N/A Although the review included many modalities of telemedicine (videoconferencing, telephone calls, etc.), 7/15 studies included mHealth; the authors were specific as to which article they were referring to in the results/discussion sections so this article is included in this integrative review.	Relevant grouping in the results section—Automated Systems: Mobile Phone Communication, Interactive Systems: Remote Disease Monitoring, Interactive Systems: Phone and Video Communication, and Smartphone Applications. Worthy amount of articles included in review (15).	Databases limited to CINAHL and Pubmed. Methodology does not identify if critical appraisal was conducted by 2 or more independent reviewers. No assessment of publication bias included.	HgbA1c improved in 10/15 studies; statistically significant in 3/10 studies (1 of those 3 mHealth). Identifies that telemedicine has promise for assisting in the management of chronic disease in the adolescent population. Identifies challenges of telemedicine: compatibility with participant's personal mobile phone, electronic health records (EHRs) are not linked directly to telemedicine systems (in studies analyzed), telemedicine interventions that require multiple log-ons often have reduced compliance amongst participants, and studies that did not include incentives for participants often had lower participants interactions. Identifies telemedicine can improve social support and interaction. No PCP or healthcare provider component included in the inclusion criteria, however the review identifies that those studies that included clinician support and

			parental involvement were more successful.
(Frøisland et al., 2012) **Title:** Improving Diabetes Care for Young People With Type 1 Diabetes Through Visual Learning on Mobile Phones: Mixed Methods Study. Mixed-methods study measuring HgbA1c, the system usability scale (SUS) of the mHealth applications, and diabetes knowledge of the participants. Level of evidence: Level IV N= 12 *Diamob*, a smartphone application which utilizes smartphone cameras and obtains blood glucose data via Bluetooth from glucometers, was created to monitor dietary intake in adolescents with T1DM, their pre/post- meal blood glucose values, the amount of insulin they administered, and physical activity information.	Strength in that the study is mixed-methods. Qualitative data analysis conducted by two authors independently. Analysis was founded on phenomenological and hermeneutic methodology to capture the participant's experiences. Dialogue from participant interviews included in the results section. Statistical analysis sufficient.	Small sample size; 12 participants (7 girls, 5 boys), 11 completed the study. No control group. Short intervention period of 3 months. Does not identify if interviews were conducted individually or in groups. All participants used insulin pumps; bias results? Quotes from qualitative study frequently from same participants, were participants' voices evenly represented?	Glycemic control improved in 7/11 participants; mean HgbA1c prior to intervention 8.3, post-intervention 8.1. HgbA1c improved in 7 participants, unchanged in 2 participants, and increased in 3 participants. The mean SUS score was 73, 10 participants had a mean score of 81; 2 participants scored 30 (a SUS greater than 80 is considered high, 58 is considered average). Participants scored similarly pre/post study on the diabetic knowledge test (mean 22, max. possible score 27). Emphasizes empowerment. Strong connection identified between visuals (photos) and ideal diabetic management (as the primary visual cortex develops earlier than areas of the brain that regulate executive function).

Furthermore, the *Diabetes Message System (DMS)* was created to send SMS messages due to strict Norwegian law. Reminder messages were sent to participants (based on the patient's self-identified educational needs) however participants could also ask questions to a physician.			Participants reported a greater understanding of the relationship between controlled blood glucose levels and insulin; increased social acceptance; greater ability to manage T1DM independently; and improved knowledge, skills, attitudes, and awareness of T1DM. Consensus from adolescents that mobile technology was useful in managing their diabetes PCP interaction: 2 physicians responded to messages received via the DMS.
(Mulvaney et al., 2012) **Title:** A pilot test of a tailored mobile and web-based diabetes messaging system for adolescents. Quasi-experimental study. Level of evidence: Level III N= 28 A messaging application, SuperEgo, was created to assist adolescents in managing T1DM.	Comparison group well-matched to participants by IT specialist not involved in the research study Participants had to own a mobile phone to participate in the study.	Study conducted over 3 months. Small sample size; 28 participants at beginning of study, 23 completed study. Average household incomes $70,000-$100,000. No confirmation that messages were read by participants during study.	The pilot group maintained their HgbA1c values however the control group experienced an increase (worsening) in their values (p= 0.006). Mobile applications are well-received and can improve outcomes. No PCP involved.

Adolescents assisted in creating messages for the app (those same adolescents were not a part of the study). Study participants then identified their top 3 barriers; 75% of the messages sent were tailored to their needs. Participants were sent approx. 8-12 messages per week for 3 months.			